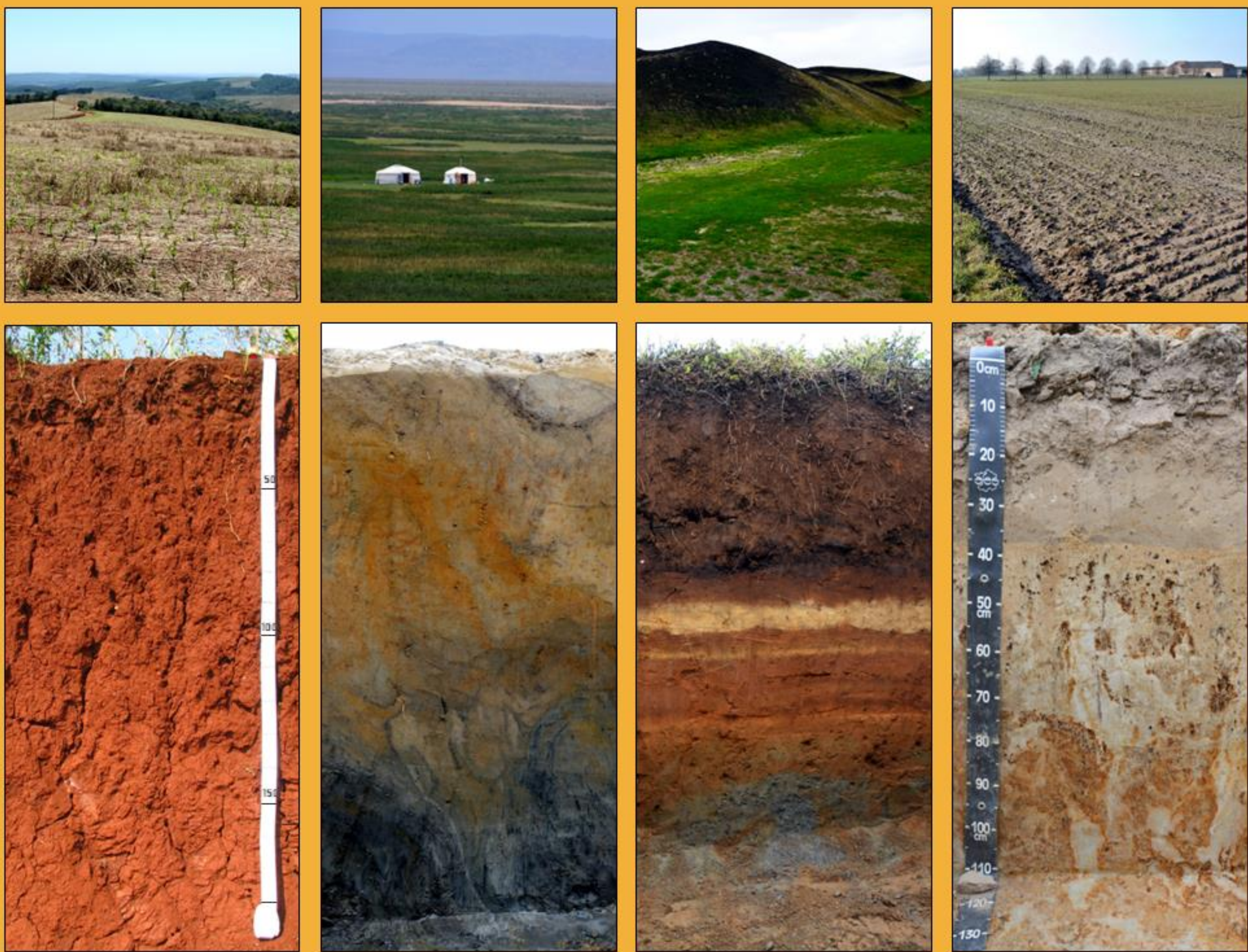
World Reference Base for Soil Resources

International soil classification system for naming soils and creating legends for soil maps

4th edition, 2022



International Union of Soil Sciences®

International Decade of Soils 2015-2024

Global Soil Icon

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Cover by Stefaan Dondeyne
From left to right:
Rhodic Ferritic Nitisol (Brazil) [photo: Sérgio Shimizu]
Stagnic Gleyic Solonchak (Mongolia) [photo: Stefaan Dondeyne]
Mollic Vitric Silandic Andosol (Iceland) [photo: Stefaan Dondeyne]
Eutric Glossic Stagnosol (Belgium) [photo: Stefaan Dondeyne]

Contents

Foreword

The soil is a living, heterogeneous and dynamic system that includes physical, chemical, biological components, and their interactions. Therefore, to assess its quality it is necessary to measure, describe, and classify its properties.

Soil classification is necessary to predict its behavior and identify limitations that allow us to make correct management decisions in the agricultural, livestock, forestry, urban, environmental, and health fields to name a few of the most important. IUSS soil scientists understood all that and the consequent urgent necessity to create an international soil classification system for name soils and create soil map legends based on a global reference system.

That is why the International Union of Soil Sciences in 1980 formed a Working Group to develop the International Reference Base for Soil Classification (IRB), in 1992 renamed the World Reference Base for Soil Resources (WRB), with the proposal of setting forth a soil classification system.

During the 16th World Congress of Soil Science in Montpellier, France, in 1998, the WRB classification was approved and adopted as the international soil correlation and communication system of the International Union of Soil Sciences (IUSS), and the first edition of the World Reference Base for Soil Resources (WRB) was presented.

In 2022, within the framework of the IUSS "International Decade of Soils 2015-2024" and with the firm commitment to offer to the international community a soil classification system to facilitate both the implementation of soil inventories and the interpretation of soil maps as practical tools for decision-making for geologists, agronomists, farmers, engineers, politicians, etc., the International Union of Soil Sciences presents the fourth edition of the World Reference Base (WRB).

The IUSS appreciates the efforts of all those who participate in the WRB working group and make the presentation of this new edition possible as an IUSS edition free to download from the IUSS website.

Laura Bertha Reyes-Sánchez
President of the International Union of Soil Sciences (IUSS)

Preface

The first edition of the World Reference Base for Soil Resources (WRB) was published in 1998, the second in 2006 and the third in 2014. In 2022, at the 22nd World Congress of Soil Science in Glasgow, we present the fourth edition.

The fourth edition is the result of another eight years of testing. During international field workshops, we classified numerous soil profiles and developed ideas for improvement. Establishing algorithms for automated classification helped overcome inconsistencies. The 32 Reference Soil Groups were maintained but soil characteristics, not reflected or properly defined up till now in the WRB, had to be taken into account. Many criteria in the diagnostics, the key and in the definitions of the qualifiers were sharpened and refined. Special effort was made to ensure consistency; that the same features are worded in the same way throughout the text, including the annexes.

The fourth edition has new annexes:

- A new Field Guide, exactly tailored to the needs of WRB, with many definitions of field characteristics, supported by numerous illustrations - it may be used instead of the FAO Guidelines for Soil Description (2006)
- Horizon and Layer Designations with master symbols and suffixes
- Recommendations for Colour Symbols for Reference Soil Group Maps
- A Soil Description Sheet and a Guidance on Database Set-Up to be provided as separate documents for download.

A large number of soil scientists contributed to the fourth edition (see Acknowledgements). We all hope that the new edition promotes a better understanding of soils, of their distribution and properties, and of their protection and sustainable management.

The first three editions of the WRB were published by the FAO in the World Soil Resources Reports series. This was no longer possible. We are glad that the present fourth edition is published by the IUSS. This reflects well the character of the WRB as a publication of an IUSS Working Group.

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Acknowledgements

The lead author of the 4th edition of the WRB is Peter Schad (Technical University of Munich, Germany).

The fundamental decisions have been made by the members of the WRB Board: Lúcia Anjos (Brazil), Jaume Boixadera Llobet (Spain), Seppe Deckers (Belgium), Stefaan Dondeyne (Belgium), Einar Eberhardt (Germany), Maria Gerasimova (Russia), Ben Harms (Australia), Cezary Kabała (Poland), Stephan Mantel (The Netherlands), Erika Michéli (Hungary), Curtis Monger (USA), Rosa Poch Claret (Spain), Peter Schad (Germany), Karl Stahr (Germany), Cornie van Huyssteen (South Africa). Vincent Buness (Germany) and Margaretha Rau (Germany) served as secretaries of the WRB Board.

The draft of the Field Guide (Annex 1) and of the Soil Description Sheet (Annex 4) were written by Vincent Buness, Margaretha Rau and Peter Schad and the draft of the Guidance on database set-up (Annex 5) by Einar Eberhardt. The figures, if not assigned otherwise, were made by Vincent Buness.

The current fourth edition received contributions from many scientists, among them are: Erhan Akça (Türkiye), Ólafur Arnalds (Iceland), David Badía Villas (Spain), Alma Barajas Alcalá (Mexico), Albrecht Bauriegel (Germany), Frank Berding (The Netherlands), Maria Bronnikova (Russia), Wolfgang Burghardt (Germany), Przemysław Charzynski (Poland), José Coelho (Brazil), Fernanda Cordeiro (Brazil), Edoardo Costantini (Italy), Jaime de Almeida (Brazil), Ademir Fontana (Brazil), Jérôme Juilleret (France/Luxembourg), Nikolay Khitrov (Russia), Aleš Kučera (Czech Republic), Eva Lehndorff (Germany), José João Lelis Leal de Souza (Brazil), João Herbert Moreira Viana (Brazil), Freddy Nachtergaele (Belgium), Otmar Nestroy (Austria), Tibor Novák (Hungary), Luis Daniel Olivares Martínez (Mexico), Thilo Rennert (Germany), Blaž Repe (Slovenia), Nuria Roca Pascual (Spain), Thorsten Ruf (Germany/Luxembourg), Alessandro Samuel-Rosa (Brazil), Tobias Sprafke (Germany/Switzerland), Marcin Świtoniak (Poland), Wenceslau Teixeira (Brazil), Łukasz Uzarowicz (Poland), Karen Vancampenhout (Belgium), Andreas Wild (Germany).

List of acronyms

Al_{ox}	Aluminium extracted by an acid ammonium oxalate solution
$CaCO_3$	Calcium carbonate
CEC	Cation exchange capacity
COLE	Coefficient of linear extensibility
EC	Electrical conductivity
EC_e	Electrical conductivity of saturation extract
ESP	Exchangeable sodium percentage
FAO	Food and Agriculture Organization of the United Nations
Fe_{dith}	Iron extracted by a dithionite-citrate-bicarbonate solution
Fe_{ox}	Iron extracted by an acid ammonium oxalate solution
HCl	Hydrochloric acid
ISRIC	International Soil Reference and Information Centre
ISSS	International Society of Soil Science
IUSS	International Union of Soil Sciences
KOH	Potassium hydroxide
KCl	Potassium chloride
Mn_{dith}	Manganese extracted by a dithionite-citrate-bicarbonate solution
NaOH	Sodium hydroxide
NH_4OAc	Ammonium acetate
RSG	Reference Soil Group
SAR	Sodium adsorption ratio
Si_{ox}	Silicon extracted by an acid ammonium oxalate solution
SiO_2	Silica
SUITMA	Soils in Urban, Industrial, Traffic, Mining and Military Areas (IUSS working group)
TRB	Total reserve of bases
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USDA	United States Department of Agriculture
WRB	World Reference Base for Soil Resources

1 Background and basics

1.1 History

From its beginnings to the third edition 2014/15

The World Reference Base for Soil Resources (WRB) is based on the Legend (FAO-Unesco, 1974) and the Revised Legend (FAO, 1988) of the Soil Map of the World (FAO-Unesco, 1971-1981). In 1980, the International Society of Soil Science (ISSS, since 2002 the International Union of Soil Sciences, IUSS) formed a Working Group 'International Reference Base for Soil Classification' for further elaboration of a science-based international soil classification system. This Working Group was renamed 'World Reference Base for Soil Resources' in 1992. The Working Group presented the first edition of the WRB in 1998 (FAO, 1998), the second edition in 2006 (IUSS Working Group WRB, 2006) and the third edition in 2014/15 (IUSS Working Group WRB, 2015). In 1998, the ISSS Council endorsed the WRB as its officially recommended terminology to name and classify soils.

A detailed description of the older WRB history is given in the second edition (IUSS Working Group WRB, 2006) and the third edition of the WRB (IUSS Working Group WRB, 2015).

From the third edition 2014 (Update 2015) to the fourth edition 2022

The third edition of the WRB was presented at the 20th World Congress of Soil Science 2014 in Jeju, Korea. In 2015, an Update was published online, which is the valid WRB from 2015 to 2022: https://www.fao.org/3/i3794en/I3794en.pdf.

The second edition was translated into several languages: Czech, French, Georgian, Polish, Russian, Slovene, and Spanish.

Since 2014, several WRB field workshops were organized to test the third edition:
2014: Ireland
2017: Latvia and Estonia
2018: Romania
2019: Mongolia
2022: Iceland
The field tours associated with the meetings of the IUSS Commission on Soil Classification in South Africa (2016) and Mexico (2022) were additional tests of the third edition and also the tours offered with the 21st World Congress of Soil Science 2018 in Brazil.

Now, after 8 years, a fourth edition has been prepared.

1.2 Major changes in WRB 2022

The major changes are:

- The contents of the book were rearranged:
  - The former Annex 1 (Descriptions) was deleted. The descriptions were not fully up to date.
  - Annex 2 (Laboratory methods) was maintained.
  - The former Annex 3 (Codes) is now Chapter 6. This reflects that the codes, if used, are not only recommended but mandatory.
  - The former Annex 4 is integrated in the new Annex 1.

- The new Annex 1 is a Field Guide. It replaces the FAO Guidelines (2006). Compared to the FAO Guidelines, the Annex 1 is more comprehensive for WRB, more precise and more didactical using many illustrations. It gives many definitions of field characteristics that up till now have been nowhere defined in WRB, neither in the WRB itself, nor in the FAO Guidelines. Many of these definitions were taken from the USDA Soil Survey Manual (2017) and the NRCS Fieldbook (2012), which brings WRB and Soil Taxonomy closer together.
    - The new Annex 3 provides brief definitions of layer symbols further developing the definitions of the FAO Guidelines.
    - The new Annex 4 explains a soil description sheet that is provided online.
    - The new Annex 5 gives a guidance on database set-up. The details are provided online.
    - The new Annex 6 gives recommendations for colour symbols for Reference Soil Group maps.
- In Chapter 2.1, General rules and definitions, several definitions have been added for WRB: fine earth, whole soil, litter layer, soil surface, mineral soil surface, soil layer, soil horizon. Some new general rules have been added to make the definitions easier.
- All Reference Soil Groups (RSGs) are maintained. There are some changes in the Key: Planosols and Stagnosols are now before Nitisols and Ferralsols. Fluvisols are before Arenosols.
- The following diagnostics were deleted:
    - fulvic horizon, melanic horizon: belonged to an outdated concept of soil organic matter;
    - aridic properties: had a non-systematic combination of various characteristics (the wind deposition is now characterized by the aeolic material, see below);
    - geric properties: can be better expressed as qualifier;
    - sulfidic material: not needed after introducing the hypersulfidic and the hyposulfidic material in 2014.
- The following diagnostics were introduced:
    - albic horizon: In the first and the second edition of WRB, the albic horizon was defined. However, it was only defined by colour, and results of soil-forming processes were not required. Therefore, it was changed to albic material in 2014. But this made the definition of the Albic qualifier difficult. Now, the albic horizon was reintroduced, explicitly requiring results of soil-forming processes. The albic material was maintained (just defined by colour) and renamed claric material (see below).
    - cohesic horizon: Dense subsurface horizon dominated by kaolinite. It is found in tropical regions with seasonal climate and was not considered so far in WRB.
    - limonic horizon: Accumulation of Fe by capillary rise in groundwater soils. The accumulation is so strong that Fe oxides cause a cementation. It is traditionally referred to as bog iron.
    - panpaic horizon: Buried A horizon.
    - tsitelic horizon: Accumulation of Fe by subsurface flow, usually from Planosols and Stagnosols further up in the landscape.
    - protogypsic properties: Accumulation of secondary gypsum, not sufficient for a gypsic or petrogypsic horizon.
    - aeolic material: Deposited by wind.
    - mulmic material: Mineral material with a high content of soil organic carbon, derived from organic material. Drainage of organic material causes accelerated decomposition, and eventually the content of soil organic carbon sinks below 20%, which transforms the organic material into mineral material.
    - organotechnic material: Contains large amounts of organic artefacts and relatively small contents of soil organic carbon in the fine earth.
- The following diagnostic materials received new names:
    - claric material instead of albic material: After reintroducing the albic horizon, it had to be avoided that a diagnostic material and a diagnostic horizon have the same name. The albic material was therefore renamed in claric material.
    - solimovic material instead of colluvic material: The word colluvium has very different meanings in

different countries. To avoid confusion, the new name solimovic material was coined. It explains that at least parts of the accumulated material underwent soil formation before having been transported.

- Many criteria in the diagnostics, the key and in the definitions of the qualifiers were sharpened and refined. Special effort was undertaken to make sure that the same features are worded in the same way throughout the text, including the annexes.
- Some new qualifiers were defined, some existing ones were deleted, and many definitions have been refined.

1.3 The object classified in the WRB

Like many common words, 'soil' has several meanings. In its traditional meaning, soil is the natural medium for the growth of plants, whether or not it has discernible soil horizons (Soil Survey Staff, 1999).

In the 1998 WRB, soil was defined as:
"… a continuous natural body which has three spatial and one temporal dimension. The three main features governing soil are:

- *It is formed by **mineral and organic constituents** and includes solid, liquid and gaseous phases.*
- *The constituents are organized in **structures**, specific for the pedological medium. These structures form the morphological aspect of the soil cover, equivalent to the anatomy of a living being. They result from the history of the soil cover and from its actual dynamics and properties. Study of the structures of the soil cover facilitates perception of the physical, chemical and biological properties; it permits understanding the past and present of the soil and predicting its future.*
- *The soil is in **constant evolution**, thus giving the soil its fourth dimension, time."*

Although there are good arguments to limit soil survey and mapping to identifiable stable soil areas with a certain thickness, the WRB has taken the more comprehensive approach to name any object forming part of the ***epiderm of the earth*** (Sokolov, 1997; Nachtergaele, 2005). This approach has a number of advantages; notably that it allows for addressing environmental problems in a systematic and holistic way and avoids sterile discussion on a universally agreed definition of soil and its required thickness and stability. Therefore, the object classified in the WRB is: *any material within 2 m of the Earth's surface that is in contact with the atmosphere, excluding living organisms, areas with continuous ice not covered by other material, and water bodies deeper than 2 m*. If explicitly stated, the object classified in the WRB includes layers deeper than 2 m. In tidal areas, the depth of 2 m is to be applied at mean low water springs.

The definition includes *continuous rock*, paved urban soils, soils of industrial areas, soils on buildings and other (permanent/stable) constructions, cave soils as well as subaqueous soils. Soils under *continuous rock*, except those that occur in caves, are generally not considered for classification, but in special cases, the WRB may be even used to classify soils under rock, for example for palaeopedological reconstruction of the environment. The use of WRB for paleosols is still in an experimental stage.

1.4 Basic principles

General principles

- The classification of soils is based on soil properties defined in terms of diagnostic horizons, diagnostic properties and diagnostic materials (together called the **diagnostics**), which to the greatest extent possible should be measurable and observable in the field. Table 1.1 provides an overview of the diagnostics used in the WRB.

- The selection of diagnostic characteristics takes into account their relationship with soil-forming processes. An understanding of soil-forming processes contributes to a better characterization of soils but these processes should not, as such, be used as differentiating criteria.
- To the extent possible at a high level of generalization, diagnostic features that are of significance for soil management are selected.
- Climate parameters are not applied in the classification of soils. It is understood that they should be used for interpretation purposes, in combination with soil properties, but they should not form part of soil definitions. The classification of soils is therefore not subordinated to the availability of climate data. The name of a certain soil will not become obsolete due to global or local climate change.
- The WRB is a comprehensive classification system that enables accommodation of national soil classification systems.
- The WRB is not intended to be a substitute for national soil classification systems, but rather to serve as a common denominator for communication at the international level.
- The WRB comprises two levels of categorical detail:
  - the ***First Level*** having 32 Reference Soil Groups (RSGs);
  - the ***Second Level***, consisting of the name of the RSG combined with a set of principal and supplementary qualifiers.
- Many RSGs in the WRB are representative of major soil regions so as to provide a comprehensive overview of the world's soil cover.
- Definitions and descriptions reflect variations in soil characteristics that occur both vertically and laterally in the landscape.
- The term *Reference Base* is connotative of the common denominator function of the WRB: its units (RSGs) have sufficient width to facilitate harmonization and correlation with national systems.
- In addition to serving as a correlation between existing classification systems, the WRB also serves as a communication tool for compiling global soil databases and for the inventory and monitoring of the world's soil resources.
- The nomenclature used to distinguish soil groups retains terms that have been used traditionally or that can be introduced easily into common language. They are defined precisely, in order to avoid the confusion that occurs where names are used with different connotations.

Table 1.1: The diagnostic horizons, properties and materials of the WRB. ***This table does not provide definitions.*** *For diagnostic criteria, please refer to Chapter 3*

	Simplified Description
1. Anthropogenic diagnostic horizons (all are mineral)	
anthraquic horizon	in paddy soils: the layer comprising the puddled layer and the plough pan, both showing a reduced matrix and oxidized root channels
hortic horizon	dark, high content of organic matter and P, high animal activity, high base saturation; resulting from long-term cultivation, fertilization and application of organic residues
hydragric horizon	in paddy soils: the layer below the anthraquic horizon showing redoximorphic features and/or an accumulation of Fe and/or Mn
irragric horizon	uniformly textured, at least moderate content of organic matter, high animal activity; gradually built up by sediment-rich irrigation water
plaggic horizon	dark, at least moderate content of organic matter, sandy or loamy; resulting from application of sods and excrements

pretic horizon	dark, at least moderate content of organic matter and P, high contents of exchangeable Ca and Mg, with black carbon; including Amazonian Dark Earths
terric horizon	evidence of addition of substantially different material, at least moderate content of organic matter, high base saturation; resulting from adding mineral material (with or without organic residues) and cultivation
2. Diagnostic horizons that may be organic or mineral	
calcic horizon	accumulation of secondary carbonates, not continuously cemented
cryic horizon	perennially frozen (visible ice or, if not enough water, < 0°C)
salic horizon	high amounts of readily soluble salts
thionic horizon	with sulfuric acid and a very low pH value
3. Organic diagnostic horizons	
folic horizon	organic layer, not water-saturated and not drained
histic horizon	organic layer, water-saturated or drained
4. Surface mineral diagnostic horizons	
chernic horizon	thick, very dark-coloured, high base saturation, moderate to high content of organic matter, well developed soil structure or structural elements created by agricultural practices, high animal activity (special case of the mollic horizon)
mollic horizon	thick, dark-coloured, high base saturation, moderate to high content of organic matter, at least some soil structure or structural elements created by agicultural practices
umbric horizon	thick, dark-coloured, low base saturation, moderate to high content of organic matter, at least some soil structure or structural elements created by agricultural practices
5. Other mineral diagnostic horizons related to the accumulation of substances due to (vertical or lateral) migration processes	
argic horizon	subsurface layer with distinctly higher clay content than the overlying layer without a lithic discontinuity and/or presence of illuvial clay minerals (with or without a lithic discontinuity)
duric horizon	concretions or nodules, cemented by secondary silica, and/or remnants of a broken-up petroduric horizon
ferric horizon	≥ 5% reddish to blackish concretions and/or nodules and/or ≥ 15% reddish to blackish coarse masses, with accumulation of Fe (and Mn) oxides
gypsic horizon	accumulation of secondary gypsum, not continuously cemented
limonic horizon	accumulation of Fe and/or Mn oxides in a layer that has or had gleyic properties; at least partially cemented
natric horizon	subsurface layer with distinctly higher clay content than the overlying layer without a lithic discontinuity and/or presence of illuvial clay minerals (with or without a lithic discontinuity); high content of exchangeable Na
petrocalcic horizon	accumulation of secondary carbonates, relatively continuously cemented
petroduric horizon	accumulation of secondary silica, relatively continuously cemented

petrogypsic horizon	accumulation of secondary gypsum, relatively continuously cemented
petroplinthic horizon	consists of oximorphic features inside (former) soil aggregates that are at least partially interconnected and have a yellowish, reddish and/or blackish colour; high contents of Fe oxides at least in the oximorphic features; relatively continuously cemented
pisoplinthic horizon	≥ 40% at least moderately cemented yellowish, reddish, and/or blackish concretions and/or nodules, with accumulation of Fe oxides, and/or remnants of a broken-up petroplinthic horizon
plinthic horizon	has in ≥ 15% of its exposed area oximorphic features inside (former) soil aggregates that are black or have a redder hue and a higher chroma than the surrounding material; high contents of Fe oxides, at least in the oximorphic features; not continuously cemented
sombric horizon	subsurface accumulation of organic matter other than in spodic or natric horizons; not a buried surface horizon
spodic horizon	subsurface accumulation of Al with Fe and/or organic matter
tsitelic horizon	lateral accumulation of Fe, usually derived from Planosols and Stagnosols further upslope
6. Other mineral diagnostic horizons	
albic horizon	light-coloured; loss of coloured substances (e.g. oxides, organic matter) due to soil-forming processes
cambic horizon	evidence of soil-forming processes; not meeting the criteria of diagnostic horizons that indicate stronger alteration or accumulation processes
cohesic horizon	massive or subangular blocky structure, root penetration restricted, drainage normally free, rich in kaolinite, poor in organic matter
ferralic horizon	strongly weathered, dominated by kaolinites and oxides
fragic horizon	with large soil aggregates, roots and percolating water penetrate the soil only in between these aggregates, not or only partially cemented
nitic horizon	rich in clay minerals and Fe oxides, moderate to strong structure, shiny soil aggregate surfaces
panpaic horizon	buried mineral surface horizon with a significant content of organic matter
protovertic horizon	influenced by swelling and shrinking clay minerals
vertic horizon	dominated by swelling and shrinking clay minerals
7. Diagnostic properties related to surface characteristics	
takyric properties	fine-textured surface crust with a platy or massive structure; under arid conditions in periodically flooded soils
yermic properties	combination of desert features: desert pavement, varnishing, ventifacts, vesicular pores, platy structure
8. Diagnostic properties defining the relationship between two layers	
abrupt textural difference	very sharp increase in clay content within a limited depth range
albeluvic glossae	interfingering of coarser-textured and lighter-coloured material into an argic horizon forming vertically continuous tongues (special case of retic properties)
lithic discontinuity	differences in parent material

retic properties	interfingering of coarser-textured and lighter-coloured material into an argic or natric horizon
9. Other diagnostic properties	
andic properties	short-range-order minerals and/or organo-metallic complexes
anthric properties	applying to soils with mollic or umbric horizons, if the mollic or umbric horizon is created or substantially transformed by humans
continuous rock	consolidated material (excluding cemented pedogenic horizons)
gleyic properties	saturated with flowing or upwards moving groundwater (or upwards moving gases), permanently or at least long enough that reducing conditions occur
protocalcic properties	carbonates derived from the soil solution and precipitated in the soil (secondary carbonates), less pronounced than in calcic or petrocalcic horizons
protogypsic properties	gypsum derived from the soil solution and precipitated in the soil (secondary gypsum), less pronounced than in gypsic or petrogypsic horizons
reducing conditions	low rH value and/or presence of sulfide, methane or reduced Fe
shrink-swell cracks	open and close due to swelling and shrinking of clay minerals
sideralic properties	relatively low CEC
stagnic properties	saturated with surface water (or intruding liquids), at least temporarily, long enough that reducing conditions occur
vitric properties	≥ 5% (by grain count) of volcanic glasses and related materials, and containing a limited amount of short-range-order minerals and/or organo-metallic complexes
10. Diagnostic materials related to the concentration of organic carbon or related to organic artefacts	
mineral material	< 20% soil organic carbon and < 35% (by volume) organic artefacts
mulmic material	developed from water-saturated organic material after drainage; 8 - 20% soil organic carbon
organic material	≥ 20% soil organic carbon
organotechnic material	< 20% soil organic carbon and ≥ 35% (by volume) organic artefacts
soil organic carbon	organic carbon that does not meet the diagnostic criteria of artefacts
11. Diagnostic material related to colour	
claric material	light-coloured fine earth, expressed by high Munsell value and low chroma
12. Technogenic diagnostic materials	
artefacts	created, substantially modified or brought to the surface by humans; no subsequent substantial change of chemical or mineralogical properties
technic hard material	consolidated and relatively continuous material resulting from an industrial process
13. Other diagnostic materials	
aeolic material	sedimented by wind
calcaric material	≥ 2% calcium carbonate equivalent, at least partially inherited from the parent material

dolomitic material	≥ 2% of a mineral that has a ratio $CaCO_3/MgCO_3 < 1.5$
fluvic material	fluviatile, marine or lacustrine deposits with evident stratification
gypsiric material	≥ 5% gypsum, at least partially inherited from the parent material
hypersulfidic material	containing sulfides and capable of severe acidification
hyposulfidic material	containing sulfides and not capable of severe acidification
limnic material	deposited in water by precipitation (possibly with sedimentation), or derived from algae, or derived from aquatic plants with subsequent transport or subsequent modification by aquatic animals or microorganisms
ornithogenic material	excrements or remnants of birds or bird activity
solimovic material	heterogeneous mixture that has moved down a slope, suspended in water; dominated by material that underwent soil formation at its original place
tephric material	≥ 30% (by grain count) volcanic glass and related materials

Structure

Each RSG of the WRB is provided with a listing of possible principal and supplementary qualifiers, from which the user can construct the second level of the classification. The principal qualifiers are given in a priority sequence. The broad principles that govern the WRB class differentiation are:

- At the ***First Level*** (RSGs), classes are differentiated mainly according to characteristic soil features produced by primary pedogenic process, except where special soil parent materials are of overriding importance.
- At the ***Second Level*** (RSGs with qualifiers), soils are differentiated according to soil features resulting from any secondary soil-forming process that has significantly affected the primary characteristics. In many cases, soil characteristics that have a significant effect on land use are taken into account.

Evolution of the system

The Revised Legend of the FAO/UNESCO Soil Map of the World (FAO, 1988) was used as a basis for the development of the WRB in order to take advantage of the international soil correlation that had already been conducted through this project and elsewhere. The first edition of the WRB, published in 1998, comprised 30 RSGs; the following editions have 32 RSGs.

1.5 Architecture

The WRB comprises two levels of categorical detail:

1. the ***First Level*** having 32 Reference Soil Groups (RSGs);
2. the ***Second Level***, consisting of the name of the RSG combined with a set of principal and supplementary qualifiers.

First Level: The Reference Soil Groups

Table 1.2 provides an overview of the RSGs and the rationale for the sequence of the RSGs in the WRB Key. The RSGs are allocated to groups on the basis of dominant identifiers, i.e. the soil-forming factors or processes that most clearly condition the soil.

Second Level: The Reference Soil Groups with their qualifiers

In the WRB, a distinction is made between **principal qualifiers** and **supplementary qualifiers**. Principal qualifiers are regarded as being most significant for a further characterization of soils of the particular RSG. They are given in a ranked order. Supplementary qualifiers give some further details about the soil. They are not ranked but listed alphabetically (exception: the supplementary qualifiers related to the texture are given first). Chapter 2 gives the rules for the use of qualifiers for naming soils and for creating map legends. Constructing the second level by adding qualifiers to the RSG has several advantages compared with a dichotomic key:

- Every soil receives the appropriate number of qualifiers. Soils with few characteristics have short names; soils with many characteristics (e.g. polygenetic soils) have longer names.
- The WRB is capable of indicating most of the soil's properties, which are incorporated into an informative soil name.
- The system is robust. Missing data do not necessarily lead to a dramatic error in the classification of a soil. If one qualifier is erroneously added or erroneously omitted based on incomplete data, the rest of the soil name remains correct.

Table 1.2: Simplified guide to the WRB Reference Soil Groups (RSGs) with codes. ***This table is not to be used as a key.*** *For full definitions, please refer to Chapter 3 and the Key (Chapter 4).*

	RSG	Code
1. Soils with thick organic layers:	Histosols	HS
2. Soils with strong human influence –		
With long and intensive agricultural use:	Anthrosols	AT
Containing significant amounts of artefacts:	Technosols	TC
3. Soils with limitations to root growth –		
Permafrost-affected:	Cryosols	CR
Thin or with many coarse fragments:	Leptosols	LP
With a high content of exchangeable Na:	Solonetz	SN
Alternating wet-dry conditions, shrink-swell clay minerals:	Vertisols	VR
High concentration of soluble salts:	Solonchaks	SC
4. Soils distinguished by Fe/Al chemistry –		
Groundwater-affected, underwater or in tidal areas:	Gleysols	GL
Allophanes and/or Al-humus complexes:	Andosols	AN
Subsoil accumulation of humus and/or oxides:	Podzols	PZ
Accumulation and redistribution of Fe:	Plinthosols	PT
Stagnant water, abrupt textural difference:	Planosols	PL
Stagnant water, structural difference and/or moderate textural difference:	Stagnosols	ST
Low-activity clays, P fixation, many Fe oxides, strongly structured:	Nitisols	NT
Dominance of kaolinite and oxides:	Ferralsols	FR
5. Pronounced accumulation of organic matter in the mineral topsoil –		
Very dark topsoil, secondary carbonates:	Chernozems	CH
Dark topsoil, secondary carbonates:	Kastanozems	KS
Dark topsoil, no secondary carbonates (unless very deep), high base status:	Phaeozems	PH
Dark topsoil, low base status:	Umbrisols	UM

6. Accumulation of moderately soluble salts or non-saline substances –		
Accumulation of, and cementation by, secondary silica:	Durisols	DU
Accumulation of secondary gypsum:	Gypsisols	GY
Accumulation of secondary carbonates:	Calcisols	CL
7. Soils with clay-enriched subsoil –		
Interfingering of coarser-textured, lighter-coloured material into a finer-textured, stronger coloured layer:	Retisols	RT
Low-activity clays, low base status:	Acrisols	AC
Low-activity clays, high base status:	Lixisols	LX
High-activity clays, low base status:	Alisols	AL
High-activity clays, high base status:	Luvisols	LV
8. Soils with little or no profile differentiation –		
Moderately developed:	Cambisols	CM
Stratified fluviatile, marine or lacustrine sediments:	Fluvisols	FL
Sandy:	Arenosols	AR
No significant profile development:	Regosols	RG

1.6 Topsoils

Topsoil characteristics are prone to rapid change with time and are therefore used only in some cases in the WRB. Several suggestions for topsoil classification systems have been made (Broll et al., 2006; Fox et al., 2010; Graefe et al., 2012; Jabiol et al., 2013; Zanella et al., 2018). They may be combined with the WRB.

1.7 Subsolum

A classification scheme for subsolum materials has been proposed by Juilleret et al. (2016, 2018) that may be combined with the WRB. Subsolum material is any material occurring below the diagnostics of WRB.

1.8 Translation into other languages

Translations into other languages are most welcome. For copyright, please contact IUSS. However, all elements of the soil names (RSG, qualifiers, specifiers) must not be translated into any other language nor transliterated into another alphabet. Soil names must preserve their grammatical form. The rules for the sequence of qualifiers must be followed in any translation. Names of RSGs and qualifiers start with capital letters.

2 The rules for naming soils and creating legends for soil maps

2.1 General rules and definitions

The following principles have to be considered for classification in WRB:

1. All data refer to the fine earth, unless stated otherwise. The **fine earth** comprises the soil constituents ≤ 2 mm. The **whole soil** comprises fine earth, coarse fragments, *artefacts*, cemented parts and dead plant residues of any size.
2. All data are given **by mass** (dried at 105° C, see Annex 2, Chapter 9.2), unless stated otherwise.
3. A **litter layer** is a loose layer that contains > 90% (by volume, related to the fine earth plus all dead plant residues) recognizable dead plant tissues (e.g. undecomposed leaves). Dead plant material still connected to living plants (e.g. dead parts of *Sphagnum* mosses) is not regarded to form part of a litter layer. The **soil surface** (0 cm) is by convention the surface of the soil after removing, if present, the litter layer and, if present, below a layer of living plants (e.g. living mosses). The **mineral soil surface** is the upper limit of the uppermost layer consisting of *mineral material* (see Chapter 3.3.11 and Annex 1, Chapter 8.3.1).
4. A **soil layer** is a zone in the soil, approximately parallel to the soil surface, with properties different from layers above and/or below it. If at least one of these properties is the result of soil-forming processes, the layer is called a **soil horizon**. In the diagnostic criteria, the term 'horizon' is mainly used for the defined diagnostic horizons. The other layers are mainly called 'layer' to make sure that the criteria apply, even if they were not regarded to be soil horizons.
5. If a criterion is worded as a conditional clause (if...) and the condition (**if-clause**) is not true, the criterion is ignored.
6. Numerical values obtained in the field or in the laboratory have to be taken as such and **must not be rounded** when compared with the threshold values in the diagnostic criteria.
7. The diagnostic criteria must be fulfilled **throughout the specified depth range**, unless stated otherwise. If a diagnostic horizon consists of several subhorizons, the diagnostic criteria (except thickness) must be fulfilled in every subhorizon separately (averages are not calculated), unless stated otherwise.
8. The term **limiting layer** used in definitions comprises *continuous rock*, *technic hard material, petrocalcic*, *petroduric*, *petrogypsic* and *petroplinthic horizons* and other cemented layers with both of the following: cementation with a class of at least moderately cemented and a continuity to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume, related to the whole soil).
9. On a **slope**, the soil is described as a vertical profile. The thickness and depth values are calculated by multiplying the vertically measured values by the cosine of the inclination angle (see Annex 1, Chapter 8.1.2) (Prietzel & Wiesmeier, 2019). This is especially important on steep slopes.

Classification consists of three steps:

Step one – detecting diagnostic horizons, properties and materials (for short: diagnostics)

Describe the soil applying the Field Guide in Annex 1 (Chapter 8). It is useful that you already in the field compile a list of the possible diagnostic horizons, properties and materials observed (see Chapter 3). Conduct the relevant analyses according to Annex 2 (Chapter 9). Then, decide on the presence of diagnostics. **For the decision, only the diagnostic criteria are relevant** - neither the name of the diagnostic, nor any other description**.** A layer may fulfil the criteria of more than one diagnostic horizon, property or material, which are then regarded as overlapping or coinciding.

Step two – allocating the soil to a Reference Soil Group

For the first level of the WRB classification, the described combination of diagnostic horizons, properties and materials and/or additional characteristics are compared to the WRB Key (Chapter 4) in order to allocate the soil to the appropriate **Reference Soil Group (RSG)**. The user must go through the Key systematically, starting at the beginning and excluding one by one all RSGs for which the specified requirements are not met. The soil belongs to the first RSG for which it fulfils the criteria.

Step three – allocating the qualifiers

For the second level of the WRB classification, qualifiers are used. The qualifiers available for use with a particular RSG are listed in the Key, along with the RSG. They are divided into principal and supplementary qualifiers.

The **principal qualifiers** are ranked and given in an order of importance. The rank of the principal qualifiers reflects particular soil characteristics or properties strongly influencing the soil's functionality:

Examples of principal qualifiers indicating subdivisions of the RSG based on soil characteristics:
- Vitric, Aluandic and Silandic for Andosols
- Carbic and Rustic for Podzols
- anthropogenic horizons: Anthraquic, Hortic, Hydragric, Irragric, Plaggic, Pretic, Terric.

These soils have distinct physico-chemical characteristics reflecting their formation.

Examples of subdivisions reflecting major functional restrictions (many of them indicate a deviation from the central image of the RSG): Abruptic, Fragic, Gleyic, Leptic, Petrocalcic, Petroduric, Petrogypsic, Petroplinthic, Retic, Skeletic, Stagnic, Thionic.

The **supplementary qualifiers** are not ranked. **Supplementary qualifiers related to the texture**, if applicable, are the first in the list. If several ones apply (see Chapter 2.3), they are placed in the sequence from the top to the bottom of the soil profile (e.g. Episiltic, Katoloamic). All **other supplementary qualifiers** follow them and are used in alphabetical order.

Qualifiers may be principal for some RSGs and supplementary for others, e.g., Turbic is principal for Cryosols and supplementary for other RSGs.

The principal qualifiers are added before the name of the RSG without brackets and without commas. The sequence is from right to left, i.e. the uppermost qualifier in the list is placed closest to the name of the RSG. The supplementary qualifiers are added in brackets after the name of the RSG and are separated from each other by commas. The sequence is from left to right, i.e. the first qualifier in the list is placed closest to the name of the RSG.

If two or more qualifiers in the list are **separated by a slash (/)**, they are either mutually exclusive (e.g. Dystric and Eutric) or one of them is redundant (see below) with the redundant qualifier(s) listed after the slash(es). In the soil name, supplementary qualifiers are placed in the order of the alphabet (exception: supplementary qualifiers related to the texture, see above), even if their position in the list differs from the alphabetical sequence due to the use of the slash.

Qualifiers that are mutually exclusive may apply to the same soil at different depths. In this case, they can be used both, each one with the respective specifier (see Chapter 2.3). If no specifier is used, only the first applicable qualifier can be used.

Qualifiers conveying redundant information are not added. This is a general rule and applies even if the slash is not used. For example, Eutric is not added if the Calcaric qualifier applies.

If qualifiers apply but are not in the list for the particular RSG, they should be added last as supplementary qualifiers. This is mainly relevant for polygenetic soils.

The names of the RSGs and the (sub)qualifiers must start with a **capital letter**.

2.2 Rules for naming soils

For naming a soil at the second level, all the principal and supplementary qualifiers that apply must be added to the name of the RSG.

Example of naming a soil according to WRB

Field description
A soil developed from loess with high-activity clays has a marked clay increase at 60 cm depth, clay coatings in the clay-rich horizon, no stratification, and a field pH value around 6 in the depth from 50 to 100 cm. The clay-poor upper soil is subdivided into a darker upper and a light-coloured lower horizon. The clay-rich horizon has a limited amount of oximorphic features with intensive colours inside the soil aggregates and *reducing conditions* in some parts during springtime. The following conclusions can be drawn (for subqualifiers see Chapter 2.3):

a.	clay increase without *lithic discontinuity* and/or with clay coatings	→ *argic horizon*
b.	*argic horizon* with high CEC, more exchangeable base cations than Al (inferred by pH 6)	→ Luvisol
c.	light colour in the eluvial horizon	→ *claric material*
d.	*claric material* above the *argic horizon*	→ *albic horizon* → Albic qualifier
e.	some oximorphic features inside aggregates	→ *stagnic properties*
f.	*stagnic properties* and *reducing conditions* starting at 60 cm	→ Endostagnic subqualifier
g.	clay coatings	→ Cutanic qualifier
h.	clay increase without *lithic discontinuity*	→ Differentic qualifier
i.	*argic horizon* starting > 50 cm and ≤ 100 cm	→ Endic qualifier

The **field classification** is Albic Endostagnic Luvisol (Cutanic, Differentic, Endic).

Laboratory analyses
The laboratory analyses confirm a high CEC kg^{-1} clay in the *argic horizon* and a high base saturation in the depth from 50 - 100 cm. They further detect the texture class of silty clay loam with 30% clay (Loamic qualifier) from 0 - 60 cm (Ano- specifier) and of silty clay with 45% clay (Clayic qualifier) from 60 - 100 cm

(Endo- specifier). The organic carbon content in the topsoil is intermediate (Ochric qualifier).

The **final classification** is Albic Endostagnic Luvisol (Anoloamic, Endoclayic, Cutanic, Differentic, Endic, Ochric).

2.3 Subqualifiers

Qualifiers may be combined with specifiers (e.g. Epi-, Proto-) **to form subqualifiers** (e.g. Epiarenic, Protocalcic). Depending on the specifier, the subqualifier fulfils all the criteria of the respective qualifier, or it deviates in a defined way from its set of criteria. The following rules apply:

1. If a subqualifier applies that fulfils all the criteria of the qualifier, the subqualifier can - but does not have to - be used instead of its qualifier (**optional subqualifiers**).
2. If a subqualifier applies that fulfils all the criteria of the qualifier except thickness and/or depth criteria, the subqualifier can - but does not have to - be used, but not the qualifier (**additional subqualifiers**). Note: It may happen that the qualifier is not listed with the available qualifiers for the respective RSG in Chapter 4.
3. If a subqualifier applies that deviates in a defined way from the set of criteria of the qualifier, the subqualifier must be used instead of the qualifier that is listed as available for the respective RSG in Chapter 4 (**mandatory subqualifiers**). This is the case for some subqualifiers with a given definition (see below).

Optional and additional subqualifiers are recommended especially for naming soils. Their use is not recommended for principal qualifiers in map units or wherever generalization is important.

The use of specifiers does not change the **position of the qualifier in the soil name** with the exception of the specifiers Bathy-, Thapto-, and Proto- (see below). Those supplementary qualifiers that are added according to the alphabet follow the alphabetical order of the qualifier, not the subqualifier.

Some subqualifiers can be constructed by the user according to certain rules (see Chapter 2.3.1). Other subqualifiers have a fixed definition given in Chapter 5 (see Chapter 2.3.2).

2.3.1 Subqualifiers constructed by the users

Constructed subqualifiers related to depth requirements

Qualifiers that have depth requirements can be combined with the specifiers **Epi-, Endo-, Amphi-, Ano-, Kato-, Poly-, Panto-** and **Bathy-** to create subqualifiers (e.g. Epicalcic, Endocalcic) further expressing the depth of occurrence. Qualifiers that are mutually exclusive at the same depth may be applicable at different depths in the same soil. Qualifiers that already have a depth range requirement of 0-50 cm or 50-100 cm of the soil surface do not require these extra depth specifiers. For every qualifier with depth requirements, the definition (Chapter 5) specifies whether the depth requirement refers **to the soil surface or to the mineral soil surface**. Subqualifiers related to depth requirements are only used if the relevant soil characteristics are **reported until ≥ 100 cm of the (mineral) soil surface or to a limiting layer**, whichever is shallower.

Depending on the particular qualifier and the particular soil characteristics, depth-related subqualifiers are used in the following different ways:

1. If a qualifier refers to a characteristic that occurs at a **specific point of depth** (e.g. Raptic), **optional subqualifiers** can be constructed with the following specifiers:

Epi- (from Greek *epi*, over): the characteristic is present somewhere ≤ 50 cm of the (mineral) soil surface and is absent > 50 and ≤ 100 cm of the (mineral) soil surface; not used if a limiting layer starts ≤ 50 cm from the (mineral) soil surface.

Endo- (from Greek *endon*, inside): the characteristic is present somewhere > 50 cm of the (mineral) soil surface and is absent ≤ 50 cm of the (mineral) soil surface. (Examples: Endoraptic: the *lithic discontinuity* is present > 50 and ≤ 100 cm from the mineral soil surface; Endocryic: the *cryic horizon* has its upper limit > 50 and ≤ 200 cm from the soil surface.)

Amphi- (from Greek *amphi*, around): the characteristic is present two or more times, once or more times somewhere ≤ 50 cm of the (mineral) soil surface and once or more times somewhere > 50 and ≤ 100 cm of the (mineral) soil surface.

2. If a qualifier refers to a **layer** (e.g. Calcic, Arenic, Fluvic), **optional subqualifiers** can be constructed with the following specifiers (see Figure 2.1):

Epi- (from Greek *epi*, over): the layer has its lower limit ≤ 50 cm of the (mineral) soil surface; and no such layer occurs between 50 and 100 cm of the (mineral) soil surface; not used if the definition of the qualifier or of the horizon requires that the layer starts at the (mineral) soil surface; if a limiting layer starts ≤ 50 cm from the mineral soil surface, the qualifier referring to the limiting layer receives the Epi- specifier and all other qualifiers remain without specifier.

Endo- (from Greek *endon*, inside): the layer starts ≥ 50 cm from the (mineral) soil surface; and no such layer occurs < 50 cm of the (mineral) soil surface. (Examples: Endocalcic: the *calcic horizon* starts ≥ 50 and ≤ 100 cm from the mineral soil surface; Endospodic: the *spodic horizon* starts ≥ 50 and ≤ 200 cm from the mineral soil surface.)

Amphi- (from Greek *amphi*, around): the layer starts > 0 and < 50 cm from the (mineral) soil surface and has its lower limit > 50 and < 100 cm of the (mineral) soil surface; and no such layer occurs < 1 cm of the (mineral) soil surface; and no such layer occurs between 99 and 100 cm of the (mineral) soil surface or directly above a limiting layer.

Ano- (from Greek *ano*, upwards): the layer starts at the (mineral) soil surface and has its lower limit > 50 and < 100 cm of the (mineral) soil surface; and no such layer occurs between 99 and 100 cm of the (mineral) soil surface or directly above a limiting layer.

Kato- (from Greek *kato*, downwards): the layer starts > 0 and < 50 cm from the (mineral) soil surface and has its lower limit ≥ 100 cm of the (mineral) soil surface or at a limiting layer starting > 50 cm from the (mineral) soil surface; and no such layer occurs < 1 cm of the (mineral) soil surface.

Poly- (from Greek *polys*, many):

a. diagnostic horizons: two or more diagnostic horizons are present at the depth required by the qualifier definition, interrupted by layers that do not fulfil the criteria of the respective diagnostic horizon;
b. other layers: two or more layers within 100 cm of the (mineral) soil surface fulfil the criteria of the qualifier, interrupted by layers that do not fulfil the criteria of the respective qualifier; and the thickness criterion is fulfilled by the sum of the thicknesses of the layers; it may or may not be fulfilled by the single layers.

Panto- (from Greek *pan*, all): the layer starts at the (mineral) soil surface and has its lower limit ≥ 100 cm of the (mineral) soil surface or at a limiting layer starting > 50 cm from the (mineral) soil surface.

Qualifiers that are mutually exclusive may occur in the same soil at different depths. In this case, they can be used both, each one with the respective specifier. If the specifiers are used with principal qualifiers, the qualifier referring to the upper layer is placed closer to the name of the RSG. If the specifiers are used with supplementary qualifiers related to the texture, the qualifiers are placed in the sequence from the top to the bottom of the profile. The sequence of the other supplementary qualifiers is according to the alphabetical position of the qualifier, not the subqualifier.

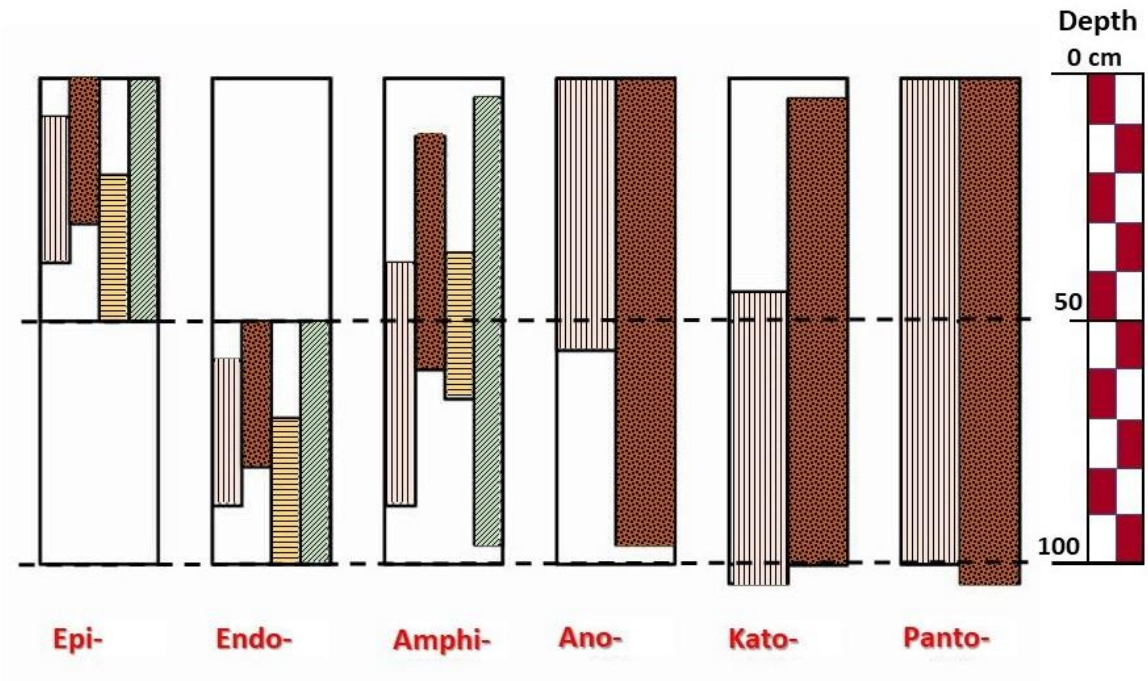

Figure 2.1: Specifiers to construct optional subqualifiers related to depth requirements and referring to a particular layer (Bathy- and Poly- not illustrated; hatching and colours just for better readability), modified by S. Dondeyne

3. If a qualifier refers to the **major part of a certain depth range or to half or more of a certain depth range** (Dystric and Eutric, only), **additional subqualifiers** can be constructed with the following specifiers:
   Epi- (from Greek *epi*, over): the characteristic is present in the major part (or half or more of the part) between the specified upper limit and 50 cm of the (mineral) soil surface and is absent in the major part (or half or more of the part) between the specified upper limit and 100 cm of the (mineral) soil surface or between the specified upper limit and a limiting layer starting > 50 cm from the mineral soil surface, whichever is shallower.
   Endo- (from Greek *endon*, inside): the characteristic is present in the major part (or half or more of the part) between 50 and 100 cm of the (mineral) soil surface or between 50 cm of the (mineral) soil surface and a limiting layer, whichever is shallower, and is absent in the major part (or half or more of the part) between the specified upper limit and 100 cm of the (mineral) soil surface or between the specified upper limit and a limiting layer, whichever is shallower.
   These additional subqualifiers are only allowed together with the predominant qualifier. If it is a principal qualifier, the predominant qualifier stands closer to the name of the RSG (Epidystric Eutric, Endodystric Eutric, Epieutric Dystric, Endoeutric Dystric). If it is a supplementary qualifier, the alphabetical sequence of the qualifiers is followed.

4. If a qualifier refers to a **specified depth range throughout** (Relocatic, only), **additional subqualifiers** can be constructed with the following specifiers:
   Epi- (from Greek *epi*, over): the characteristic is present throughout between the (mineral) soil surface and 50 cm of the (mineral) soil surface and is absent in some layer between 50 and 100 cm of the (mineral) soil surface.
   Endo- (not applicable).

5. If a qualifier refers to a **percentage** (e.g. Skeletic), **additional subqualifiers** can be constructed with the

following specifiers (no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface):

Epi- (from Greek *epi*, over): the characteristic is present between the (mineral) soil surface and 50 cm of the (mineral) soil surface but is not present throughout, i.e., if averaged over a depth of 100 cm of the (mineral) soil surface or between the (mineral) soil surface and a limiting layer, whichever is shallower.

Endo- (from Greek *endon*, inside): the characteristic is present between 50 and 100 cm of the (mineral) soil surface or between 50 cm of the (mineral) soil surface and a limiting layer, whichever is shallower, but is not present throughout, i.e., if averaged over a depth of 100 cm of the (mineral) soil surface or between the (mineral) soil surface and a limiting layer, whichever is shallower.

6. If a qualifier refers to a specific point of depth or to a layer, but its criteria are only fulfilled if layers at a depth of > 100 cm of the (mineral) soil surface are taken into account, the **Bathy-** (from Greek *bathys*, deep) specifier can be used to construct **additional subqualifiers**. The Bathy- subqualifier extends to a greater depth than specified for the qualifier. If the Endo- specifier cannot be added to a qualifier, the Bathy- specifier cannot be used either (e.g. Alcalic: neither Endo-, nor Bathy-). If used with a principal qualifier, the Bathy- subqualifier **must shift to the supplementary qualifiers** and be placed within the list of the supplementary qualifiers according to the alphabetical position of the qualifier, not the subqualifier. With the Bathy- specifier, qualifiers that are not even in the list for the particular RSG (see Chapter 4) can be added, for example Eutric Arenosol (Bathylixic). If it comprises buried layers, Bathy- is only allowed in combination with the Thapto- specifier, e.g. Thaptobathyvertic (see the Thapto- specifier, below, and Chapter 2.4).

Note: Specifiers conveying redundant information are not added. For example: Skeletic Epileptic Cambisol, not: Episkeletic Epileptic Cambisol.

Constructed subqualifiers related to other requirements

If a diagnostic horizon or a layer with a diagnostic property belongs to a buried soil (see Chapter 2.4), the **Thapto-** (from Greek *thaptein*, to bury) specifier can be used to construct **optional or additional subqualifiers**. If used with a principal qualifier, the Thapto- subqualifier **must shift to the supplementary qualifiers** and be placed within the list of the supplementary qualifiers according to the alphabetical position of the qualifier, not the subqualifier.

For soils with a limiting layer, a geomembrane or a continuous layer of *artefacts*, **additional subqualifiers** with the **Supra-** (from Latin *supra*, above) specifier can be constructed to describe the soil material above, if the thickness or depth requirements of a qualifier or of its respective diagnostics are not fulfilled, but all other criteria are fulfilled throughout in the soil material above (e.g. Ekranic Technosol (Suprafolic)).

2.3.2 Subqualifiers with a given definition

For some qualifiers, subqualifiers are defined in Chapter 5, e.g., Hypersalic and Protosalic for the Salic qualifier. These **subqualifiers are not listed with the RSGs in Chapter 4** (unless the qualifier without specifier cannot exist for the respective RSG). They belong to the **optional** (e.g. Hypercalcic, Orthomineralic), the **additional** (e.g. Akromineralic) or the **mandatory** (e.g. Protocalcic) subqualifiers. If the **Proto-** specifier is used with a principal qualifier, the Proto- subqualifier **must shift to the supplementary qualifiers** and be placed within the list of the supplementary qualifiers according to the alphabetical position of the qualifier, not the subqualifier.

If of one qualifier, two or more subqualifiers with a given definition apply (e.g. Anthromollic and

Tonguimollic), they **have to be listed all**. Adding a further specifier to a subqualifier with a given definition is also allowed, e.g., Endoprotosalic, Supraprotosodic.

2.4 Buried soils

A buried soil is a soil covered by younger deposits. Where a soil is buried, the following rules apply:

1. The overlying material and the buried soil are classified as one soil if both together qualify as a Histosol, Anthrosol, Technosol, Cryosol, Leptosol, Vertisol, Gleysol, Andosol, Planosol, Stagnosol, Fluvisol, Arenosol or Regosol.
2. Otherwise, the overlying material is classified with preference if it is ≥ 50 cm thick or if the overlying material, if it stood alone, satisfies the requirements of a RSG other than a Regosol. For depth requirements in the overlying material, the lower limit of the overlying material is regarded as if it were the upper limit of *continuous rock*.
3. In all other cases, the buried soil is classified with preference. For depth requirements in the buried soil, the upper limit of the buried soil is regarded as its soil surface.
4. If the overlying soil is classified with preference, there are two options to consider the underlying soil:
   a. If the underlying soil is not a Regosol or Leptosol and shows a complete horizon sequence, including clearly identifiable organic surface layers and/or mineral topsoil horizons, and one soil does not influence the pedogenic processes in the other soil, respectively (e.g. no clay migration from the overlying into the underlying soil, no Fe transport by capillary upward movement from the underlying into the overlying soil), then the name of the buried soil is placed after the name of the overlying soil adding the word 'over' in between, e.g. Skeletic Umbrisol (Siltic) over Albic Podzol (Arenic). As many buried soils are polygenetic, qualifiers that are not in the list for the particular RSG may be applicable. If so, these qualifiers must be used as supplementary qualifiers. The qualifiers Infraandic and Infraspodic are provided for buried soils only and are therefore not listed with the RSGs in Chapter 4. As all non-listed qualifiers, they are added as last supplementary qualifiers.
   b. Otherwise, a buried diagnostic horizon or a buried layer with a diagnostic property is added with the Thapto- subqualifier to the name of the overlying soil (see Chapter 2.3).
5. If the buried soil is classified with preference, the overlying material is indicated with the Novic qualifier. If applicable, the Novic qualifier is combined with certain other qualifiers in the following way (codes in brackets); thickness and depth criteria of these qualifiers do not need to be fulfilled:
   Aeoli-Novic (nva)
   Fluvi-Novic (nvf)
   Solimovi-Novic (nvs)
   Techni-Novic (nvt)
   Tephri-Novic (nvv)
   Transporti-Novic. (nvp)
   In addition, according to Chapter 5, the texture may also be added, e.g., Aeoli-Siltinovic (sja).

2.5 Guidelines for creating legends for soil maps

The following guidelines apply:

1. A map unit consists of
   - a dominant soil only
   - a dominant soil plus a codominant soil and/or one or more associated soils
   - two or three codominant soils
   - two or three codominant soils plus one or more associated soils.

Dominant soils represent ≥ 50% of the soil cover, codominant soils ≥ 25 and < 50% of the soil cover. Associated soils represent ≥ 5 and < 25% of the soil cover or are of high relevance in the landscape. Further soils should be ignored in the denomination of the map unit.

If codominant or associated soils are indicated, the words 'dominant:', 'codominant:' and 'associated:' are written before the name of the soil; the soils are separated by semicolons.

2. The number of qualifiers specified below refers to the dominant soil. For codominant or associated soils, fewer numbers of qualifiers (or even no qualifier) may be appropriate.

3. Depending on scale, different numbers of principal qualifiers are used:
   a. For very small map scales, only the Reference Soil Group (RSG) is used.
   b. For next larger map scales, the RSG plus the first applicable principal qualifier are used.
   c. For next larger map scales, the RSG plus the first two applicable principal qualifiers are used.

   It is not possible to give general figures for these scales, because this depends very much on the homogeneity or heterogeneity of the landscape. In landscapes of intermediate homogeneity, very small scales would be smaller than 1 : 10 000 000, the next larger scales smaller than 1 : 5 000 000 and the next larger scales smaller than 1 : 1 000 000.

4. If there are fewer qualifiers applicable than described above, the lesser number is used.

5. Depending on the purpose of the map or according to national traditions, at any scale level, further qualifiers may be added as **elective qualifiers**. These may be principal qualifiers from further down the list and not already used in the soil name, or they may be supplementary qualifiers. They are placed using the above-mentioned rules for supplementary qualifiers. If two or more elective qualifiers are used, the following rules apply:
   a. the principal qualifiers are placed first, and of them, the first applicable qualifier is placed first, and
   b. the sequence of any supplementary qualifiers added is decided by the soil scientist who makes the map.

Example for creating a map unit in WRB

A landscape usually shows a variety of soils. For a map unit, they often have to be combined. The principles are shown in Figure 2.2 and in Table 2.1 and Table 2.2.

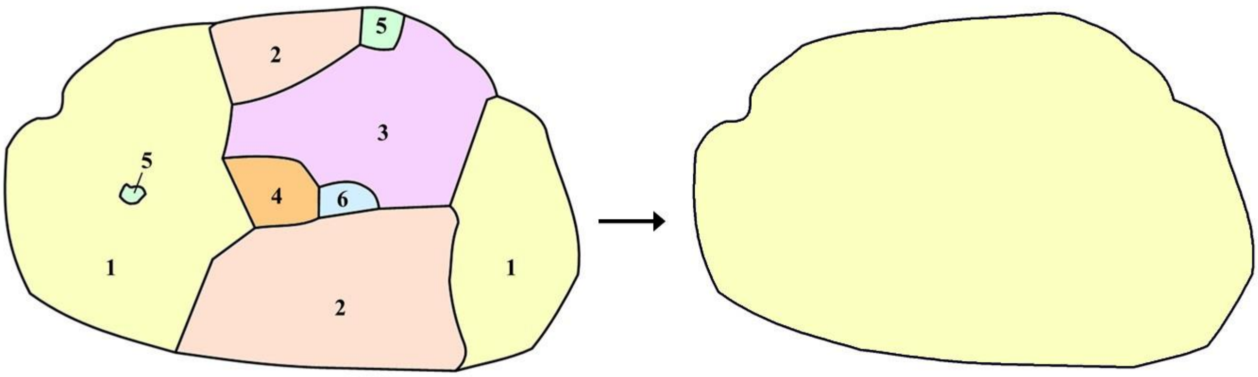

Figure 2.2: Soils in a landscape that need to be combined to form a map unit

Table 2.1: Detection of dominant, codominant and associated soils

Area	Complete soil name	Result
1	Haplic Luvisol (Episiltic, Katoclayic, Aric, Cutanic, Differentic, Epic, Ochric)	dominant soil
2	Eutric Stagnic Leptic Cambisol (Loamic, Humic)	codominant soil
3	Albic Stagnic Luvisol (Anosiltic, Endoclayic, Cutanic, Differentic, Endic, Humic)	associated soil
4	Thyric Technosol (Loamic, Calcaric, Skeletic)	ignored
5	Eutric Luvic Stagnosol (Episiltic, Katoclayic, Humic)	ignored
6	Hortic Anthrosol (Loamic, Eutric)	ignored

Table 2.2: Denomination of the map unit depending on the scale level

Map scale level	Dominant soil	Codominant soil	Associated soil
First	Luvisols	Cambisols	
Second	Haplic Luvisols	Leptic Cambisols	Stagnic Luvisols
Third	Haplic Luvisols	Stagnic Leptic Cambisols	Albic Stagnic Luvisols

Examples for map units in WRB

Example 1

A map unit dominated by a soil with a very dark mineral surface horizon, 30 cm thick, with high base saturation, no secondary carbonates and groundwater influence starting at 60 cm from the mineral soil surface (i.e. having a layer, ≥ 25 cm thick, that has *gleyic properties* throughout and *reducing conditions* in some parts of every sublayer), will be named as follows:

- at the first map scale level: Phaeozems
- at the second map scale level: Chernic Phaeozems
- at the third map scale level: Gleyic Chernic Phaeozems

Example 2

In a map unit, no diagnostics apply. In 80% of the area, the soil has < 40% coarse fragments as a weighted average in the uppermost 100 cm, in the other 20% of the area, the soil has 85% coarse fragments as a weighted average in the uppermost 75 cm. The soils are calcareous and silty. This map unit will be named as follows:

- at the first map scale level: dominant: Regosols
associated: Leptosols
- at the second map scale level: dominant: Calcaric Regosols
associated: Coarsic Leptosols
- at the third map scale level: dominant: Calcaric Regosols
associated: Calcaric Coarsic Leptosols

In this example, the next applicable qualifier for the Regosols is Eutric. However, as high base saturation is already indicated by the Calcaric qualifier, the Eutric qualifier is redundant. Therefore, in this case, only one principal qualifier is applicable at the third map scale level. For associated soils, it is allowed to use fewer qualifiers than indicated for the scale level. If appropriate, at the third scale level, the Leptosols may just be named Coarsic Leptosols.

The high silt content may be expressed by the Siltic qualifier, which as a supplementary qualifier is elective in a map legend. It may be added at any scale level, for example:

- at the first map scale level: Regosols (Siltic)
- at the second map scale level: Calcaric Regosols (Siltic)

Principal qualifiers, not required at the respective scale level, may also be added as elective qualifiers, for example:

- at the first map scale level: Regosols (Calcaric, Siltic)
- at the second map scale level: Calcaric Regosols (Siltic)

Example 3
A map unit, dominated by a soil with a thick layer of strongly decomposed acidic *organic material*, 70 cm thick and filled with rainwater, with *continuous rock* at 80 cm will be named as follows:

- at the first map scale level: Histosols
- at the second map scale level: Sapric Histosols
- at the third map scale level: Leptic Sapric Histosols

In this example, the next applicable qualifier is Ombric. As two qualifiers are already used, the third may be added as elective qualifier. In a similar way, elective qualifiers may be used at the other scale levels, for example:

- at the first map scale level: Histosols (Sapric)
- at the second map scale level: Sapric Histosols (Leptic, Ombric)
- at the third map scale level: Leptic Sapric Histosols (Ombric)

3 Diagnostic horizons, properties and materials

Before using the diagnostic horizons, properties and materials, please read the 'Rules for naming soils' (Chapter 2).

Throughout the following text, references to the RSGs defined in Chapter 4 and to the diagnostics listed elsewhere in this Chapter are shown in *italics*.

3.1 Diagnostic horizons

Diagnostic horizons are characterized by a combination of attributes that reflect widespread, common results of soil-forming processes. Their features can be observed or measured in the field or the laboratory and require a minimum or maximum expression to qualify as diagnostic. In addition, diagnostic horizons require a certain minimum thickness, thus forming a recognizable layer in the soil.

3.1.1 Albic horizon

General description

An albic horizon (from Latin *albus*, white) is a light-coloured horizon overlying an *argic*, *natric*, *plinthic* or *spodic horizon* or forming part of a layer with *stagnic properties*. It has low contents of Fe and Mn (depleted from both oxidized and reduced forms) and of organic matter, and at least one of these substances has previously been present and was lost due to clay migration, podzolization, and/or redox processes caused by water stagnation.

Diagnostic criteria

An albic horizon consists of *mineral material* and

1. consists of *claric material*;
   and
2. one or both of the following:
   a. overlies an *argic*, *natric*, *plinthic* or *spodic horizon*; ***or***
   b. forms part of a layer with *stagnic properties*;
   and
3. has a thickness of ≥ 1 cm.

Additional information

Albic horizons are normally overlain by humus-enriched surface layers but may also be at the mineral soil surface as a result of erosion or artificial removal of the surface layer. Many albic horizons represent a strong expression of eluviation and are therefore called eluvial horizons. In sandy materials, albic horizons can reach considerable thickness, up to several metres, especially in humid tropical regions, and underlying diagnostic horizons may be hard to establish. Albic horizons generally have a weakly expressed soil aggregate structure, a single grain structure or a massive structure. Albic horizons are widely depleted from Fe, both the oxidized and the reduced forms, and typically do not show red colours when applying α,α-dipyridyl solution.

Relationships with some other diagnostics

While the albic horizon is the result of soil-forming processes, the *claric material* is only defined by colour criteria, and layers with *claric material* may or may not have undergone soil-forming processes. The

definition of the albic horizon uses the *argic*, *natric*, *plinthic* or *spodic* horizon or the *stagnic porperties* as criterion. The definitions of the *spodic horizon* and of the *retic* and *stagnic properties*, in turn, use the *claric material* as criterion.
Many albic horizons that were formed by stagnant water do not show active *reducing conditions*.

3.1.2 Anthraquic horizon

General description

An anthraquic horizon (from Greek *anthropos*, human being, and Latin *aqua*, water) is a surface horizon that results from wet-field cultivation and comprises a *puddled layer* and a *plough pan.*

Diagnostic criteria

An anthraquic horizon is a surface horizon consisting of *mineral material* and has:

1. a puddled layer with the following Munsell colours, moist, in ≥ 80% of its exposed area:
   a. a hue of 7.5YR or yellower, a value of ≤ 4 and a chroma of ≤ 2; ***or***
   b. a hue of GY, B or BG and a value of ≤ 4;
   and
2. a plough pan underlying the puddled layer, with all of the following:
   a. one or both of the following:
      i. a platy structure in ≥ 25% of its volume; ***or***
      ii. a massive structure in ≥ 25% of its volume;
      and
   b. a bulk density higher by ≥ 10% (relative) than that of the puddled layer;
      and
   c. oximorphic features, in ≥ 5% of its exposed area (related to the fine earth plus oximorphic features of any size and any cementation class), that:
      i. are predominantly on biopore walls and, if soil aggregates are present, predominantly on or adjacent to aggregate surfaces; ***and***
      ii. have a Munsell colour hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher, moist, than the surrounding material;
   and
3. a thickness of ≥ 15 cm.

Field identification

An anthraquic horizon shows evidence of reduction and oxidation owing to flooding for part of the year. When not flooded, it is very dispersible and has a loose packing of sorted small soil aggregates. The plough pan is compact, has a platy or massive structure and a very low infiltration rate. It has a reduced matrix and yellowish-brown, brown or reddish-brown oximorphic features along cracks and root channels due to oxygen release from plant roots.

Relationships with some other diagnostics

After a long time of wet-field cultivation, a *hydragric horizon* develops under the anthraquic horizon.

3.1.3 Argic horizon

General description

An argic horizon (from Latin *argilla*, white clay) is a subsurface horizon with a distinctly higher clay content than the overlying horizon. The textural differentiation may be caused by:

- an illuvial accumulation of clay minerals
- predominant pedogenic formation of clay minerals in the subsoil
- destruction of clay minerals in the overlying horizon
- selective surface erosion of clay minerals
- upward movement of coarser particles due to swelling and shrinking
- biological activity, or
- a combination of two or more of these different processes.

Iron (hydr)oxides are often accumulated or formed together with clay minerals, giving the argic horizon a redder hue and/or a higher chroma.

A clay-richer stratum overlain by a clay-poorer stratum may resemble an argic horizon. However, a textural difference due only to a *lithic discontinuity* does not qualify as an argic horizon. In some soils, we may have both: a clay-poorer stratum overlying a clay-richer stratum and additionally a textural differentiation caused by soil-forming processes.

Diagnostic criteria

An argic horizon consists of *mineral material* and:

1. has a texture class of loamy sand or finer and ≥ 8% clay;
   and
2. one or both of the following:
   a. has an overlying coarser-textured layer with all of the following:
      i. the coarser-textured layer is not separated from the argic horizon by a *lithic discontinuity*; ***and***
      ii. if the coarser-textured layer directly overlies the argic horizon, its lowermost sublayer does not form part of a plough layer; ***and***
      iii. if the coarser-textured layer does not directly overlie the argic horizon, the transitional horizon between the coarser-textured layer and the argic horizon has a thickness of ≤ 15 cm; ***and***
      iv. if the coarser-textured layer has < 15% clay, the argic horizon has ≥ 6% (absolute) more clay; ***and***
      v. if the coarser-textured layer has ≥ 15 and < 50% clay, the ratio of clay in the argic horizon to that of the coarser-textured layer is ≥ 1.4; ***and***
      vi. if the coarser-textured layer has ≥ 50% clay, the argic horizon has ≥ 20% (absolute) more clay;
      or
   b. has evidence of illuvial clay in one or more of the following forms:
      i. clay bridges connecting ≥ 15% of the sand grains; ***or***
      ii. clay coatings covering ≥ 15% of the surfaces of soil aggregates, coarse fragments and/or biopore walls; ***or***
      iii. in thin sections, oriented clay bodies that constitute ≥ 1% of the section and that have not been transported laterally after they had been formed; ***or***
      iv. a ratio of fine clay to total clay in the argic horizon greater by ≥ 1.2 times than the ratio in the overlying coarser-textured layer;

   and
3. both of the following:
   a. does not form part of a *natric horizon*; ***and***
   b. does not form part of a *spodic horizon*, unless illuvial clay is evidenced by one or more of the diagnostic criteria listed under 2.b;

   and
4. has a thickness of one-tenth or more of the thickness of the overlying *mineral material*, if present, and one of the following:
   a. ≥ 7.5 cm (if composed of lamellae: combined thickness within 50 cm of the upper limit of the uppermost lamella) if the argic horizon has a texture class of sandy loam or finer; ***or***

b. ≥ 15 cm (if composed of lamellae: combined thickness within 50 cm of the upper limit of the uppermost lamella).

Field identification

Textural differentiation and the evidence of clay illuviation are the main features of argic horizons. The recognition of clay coatings and clay bridges is explained in Annex 1 (Chapter 8.4.23).
In shrink-swell soils, clay coatings at soil aggregate surfaces are easily confused with pressure faces (stress cutans). Pressure faces do not differ in colour from the original aggregate and do not occur on coarse fragments and biopore walls.

Additional information

The illuvial character of an argic horizon can best be established using thin sections. Diagnostic illuvial argic horizons show areas with oriented clay bodies that constitute on average ≥ 1% of the entire cross-section. Other tests involved are particle-size distribution analysis to determine the increase in clay content over a specified depth, and the fine clay/total clay ratio. In illuvial argic horizons, the fine clay to total clay ratio is larger than in the overlying horizons, due to preferential transport of fine clay particles.
If the soil shows a *lithic discontinuity* directly over the argic horizon, or if the surface horizon has been removed by erosion, or if a plough layer directly overlies the argic horizon, then the illuvial nature must be clearly established (diagnostic criterion 2.b).
The argic horizon may be subdivided into several lamellae with coarser-textured layers in between.

Relationships with some other diagnostics

Argic horizons are normally situated below eluvial horizons i.e. horizons from which clay minerals have been removed, commonly together with oxides and some organic matter. Although initially formed as a subsurface horizon, argic horizons may occur at the mineral soil surface as a result of erosion or removal of the overlying horizons. Afterwards, new sediments may be added.
Some argic horizons fulfil all the diagnostic criteria of the *ferralic horizon*. Ferralsols must have a *ferralic horizon* and may have an argic horizon as well, which may or may not overlap with the *ferralic horizon*; but if an argic horizon is present, it must have in its upper 30 cm: < 10% water-dispersible clay or a ΔpH (pH_{KCl} - pH_{water}) ≥ 0 or ≥ 1.4% *soil organic carbon*.
Argic horizons lack the sodium saturation characteristics of the *natric horizon*.
Argic horizons in freely drained soils of high plateaus and mountains in humid tropical and subtropical regions may occur in association with *sombric horizons*.

3.1.4 Calcic horizon

General description

A calcic horizon (from Latin *calx*, lime) is a horizon in which secondary calcium carbonate ($CaCO_3$) has accumulated as discontinuous concentrations. The accumulation usually occurs in subsurface layers, or more rarely, in surface horizons. The calcic horizon may contain primary carbonates as well.

Diagnostic criteria

A calcic horizon:

1. has a calcium carbonate equivalent of ≥ 15% (related to the fine earth plus accumulations of secondary carbonates of any size and any cementation class);
   and
2. one or both of the following:
   a. meets the diagnostic criteria of *protocalcic properties*; ***or***

b. has a calcium carbonate equivalent of ≥ 5% higher (absolute, related to the fine earth plus accumulations of secondary carbonates of any size and any cementation class) than that of an underlying layer and no *lithic discontinuity* between the two layers;

and

3. does not form part of a *petrocalcic horizon*;

and

4. has a thickness of ≥ 15 cm.

Field identification

Calcium carbonate can be identified in the field using 1 *M* hydrochloric acid (HCl) solution. The degree of effervescence is an indication of its amount (see Annex 1, Chapter 8.4.25).
Secondary carbonates are visible as usually discrete permanent accumulations (see Annex 1, Chapter 8.4.25). In the calcic horizon, they are predominantly non-cemented or less than moderately cemented. However, discontinuous accumulations, which are moderately or more cemented, may also occur.
Other possible indications of a calcic horizon are:

- white, pinkish to reddish, or grey colours (if not overlapping horizons rich in organic carbon)
- a low porosity (interaggregate porosity is usually less than in the horizon directly above, and possibly also less than in the horizon directly below).

When sampling, please make sure that the sample includes the accumulations of secondary carbonates in order to obtain the laboratory data for criteria 1 and 2.b.

Additional information

The determination of carbonates in the laboratory (Annex 2, Chapter 9.9) uses an acid and measures the evolved CO_2. It may stem from various carbonates, but the carbonate content is calculated as if it were only from calcium carbonate. This is called the **calcium carbonate equivalent**.
Determination of the amount of calcium carbonate (by mass) and the changes of calcium carbonate content within the soil profile are the main analytical criteria for establishing the presence of a calcic horizon. *Lithic discontinuities* and any change of water permeability may favour the formation of secondary carbonates.
Determination of pH_{water} enables distinction between accumulations with a basic (*calcic*) character (pH 8–8.7) due to the dominance of $CaCO_3$, and those with an ultrabasic (*non-calcic*) character (pH > 8.7) because of the presence of Na_2CO_3 and/or $MgCO_3$.
In addition, the analysis of thin sections may reveal the presence of calcium carbonate pedofeatures (e.g. nodules, pendents) or evidence of silicate epigenesis (calcite pseudomorphs after primary minerals), besides evidences of removal of carbonates in layers above or below the calcic horizon.
If the accumulation of soft carbonates is such that all or most of the soil structure and/or rock structure disappears and continuous concentrations of calcium carbonate prevail, the Hypercalcic qualifier is used.

Relationships with some other diagnostics

When calcic horizons become continuously cemented with a cementation class of at least moderately cemented, transition takes place to the *petrocalcic horizon*, the expression of which may be massive or platy. A calcic horizon and a *petrocalcic horizon* may overlie each other.
Accumulations of secondary carbonates, not qualifying for a calcic horizon, may fulfil the diagnostic criteria of *protocalcic properties*, which are fulfilled by most calcic horizons as well. *Calcaric material* includes primary carbonates.
In dry regions and in the presence of sulfate-bearing soil or groundwater solutions, calcic horizons occur associated with *gypsic horizons*. Calcic and *gypsic horizons* typically (but not always) occupy different positions in the soil profile because gypsum is more soluble than calcium carbonate, and they can normally be distinguished clearly from each other by a difference in crystal morphology. Gypsum crystals tend to be

needle-shaped, usually visible to the naked eye, whereas pedogenic calcium carbonate crystals are much finer in size.

3.1.5 Cambic horizon

General description

A cambic horizon (from Latin *cambire*, to change) is a subsurface horizon showing evidence of soil formation that ranges from weak to relatively strong. The cambic horizon shows soil aggregate structure at least in half of the volume of the fine earth. If the underlying layer has the same parent material, the cambic horizon usually shows higher oxide and/or clay contents than this underlying layer and/or evidence of removal of carbonates and/or gypsum. The soil formation in a cambic horizon can also be established by contrast with one of the overlying mineral horizons that are generally richer in organic matter and therefore have a darker and/or less intense colour.

Diagnostic criteria

A cambic horizon consists of *mineral material* and:

1. has a texture class of
   a. sandy loam or finer; ***or***
   b. very fine sand or loamy very fine sand;
   and
2. has soil aggregate structure in ≥ 50% (by volume);
   and
3. shows evidence of soil formation in one or more of the following:
   a. compared to the directly underlying layer, not separated from the cambic horizon by a *lithic discontinuity,* one or more of the following:
      i. if the underlying layer has a Munsell colour hue of 5YR or redder, a hue ≥ 2.5 units yellower, else a hue ≥ 2.5 units redder, all moist and in ≥ 90% of its exposed area; ***or***
      ii. a Munsell colour chroma ≥ 1 unit higher, moist and in ≥ 90% of its exposed area; ***or***
      iii. a clay content ≥ 4% (absolute) higher;
   or
   b. compared to an overlying mineral layer, ≥ 5 cm thick and not separated from the cambic horizon by a *lithic discontinuity,* one or more of the following:
      i. a Munsell colour hue ≥ 2.5 units redder, moist and in ≥ 90% of its exposed area; ***or***
      ii. a Munsell colour value ≥ 1 unit higher, moist and in ≥ 90% of its exposed area; ***or***
      iii. a Munsell colour chroma ≥ 1 unit higher, moist and in ≥ 90% of its exposed area;
   or
   c. compared to the directly underlying layer, not showing *gleyic properties* and not forming part of a *calcic* or *gypsic horizon,* evidence of removal of carbonates or gypsum by one or more of the following:
      i. ≥ 5% (absolute) less calcium carbonate equivalent or ≥ 5% (absolute) less gypsum and no *lithic discontinuity* between this underlying layer and the cambic horizon; ***or***
      ii. *protocalcic properties* or *protogypsic properties* in the underlying layer but not in the cambic horizon;
   or
   d. all of the following:
      i. Fe_{dith} ≥ 0.1%; ***and***
      ii. a ratio between Fe_{ox} and Fe_{dith} of ≥ 0.1; ***and***

   iii. a Munsell colour hue of 2.5YR to 2.5Y and a chroma of > 3, all moist and in ≥ 90% of its exposed area;

   and

4. does not form part of a plough layer, does not form part of an *albic*, *anthraquic, argic, calcic, duric, ferralic, fragic, gypsic, hortic, hydragric, irragric, limonic, mollic, natric, nitic, petrocalcic, petroduric, petrogypsic, petroplinthic, pisoplinthic, plaggic, plinthic, pretic, salic, sombric, spodic, umbric, terric, tsitelic* or *vertic horizon* and does not from part of a layer with *andic properties*;

   and

5. has a thickness of ≥ 15 cm.

Additional characteristics

In many cambic horizons, Fe oxides are formed, which give the horizon a redder hue and a higher chroma. However, if the parent material has much hematite, the formation of goethite in cooler and humid conditions usually makes it yellower.

Dissolution of carbonates or gypsum is a widespread feature of cambic horizons in both humid and semi-arid environments. In many cases, this may be proven by a lesser carbonate or gypsum content compared to the underlying layer. However, in some soils, especially in arid and semi-arid areas, this lesser content is not evident. In these soils, the presence of *protocalcic* or *protogypsic properties* in the underlying layer is a proof that carbonates or gypsum have been dissolved in the horizon above. On the other hand, such accumulations may also be caused by ascending groundwater in soils with *gleyic properties*, and *gleyic properties* have to be excluded in the underlying layer for this comparison.

Relationships with some other diagnostics

The cambic horizon can be considered the predecessor of many other diagnostic horizons, all of which have specific properties that are not or only weakly expressed in the cambic horizon – such as illuvial or residual accumulations, removal of substances other than carbonates or gypsum, accumulation of soluble components, or the development of specific soil structure like wedge-shaped aggregates.

Cambic horizons in freely drained soils of high plateaus and mountains in humid tropical and subtropical regions may occur in association with *sombric horizons*. The ratio between Fe_{ox} and Fe_{dith} differentiates the cambic horizon from the *tsitelic horizon* (higher ratio). The *plinthic* and the *petroplinthic horizon* have usually much higher Fe_{dith} contents.

3.1.6 Chernic horizon

General description

A chernic horizon (from Russian *chorniy*, black) is a relatively thick, well-structured, very dark-coloured surface horizon, with a high base saturation, a high animal activity and a moderate to high content of organic matter.

Diagnostic criteria

A chernic horizon is a surface horizon consisting of *mineral material* and has:

1. ≥ 50% (by volume, weighted average, related to the whole soil) fine earth and does not consist of *mulmic material*;

   and

2. single or in combination, in ≥ 90% (by volume):
   a. granular structure; ***or***
   b. subangular blocky structure with an average aggregate size of ≤ 2 cm; ***or***
   c. cloddy structure or other structural elements created by agricultural practices;

and

3. ≥ 1% *soil organic carbon*;

   and

4. one of the following:
   a. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 2 moist;

      or

   b. all of the following:
      i. ≥ 15 and < 40% calcium carbonate equivalent; ***and***
      ii. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 3 and a chroma of ≤ 2, both moist; ***and***
      iii. ≥ 1.5% *soil organic carbon*;

      or

   c. all of the following:
      i. ≥ 40% calcium carbonate equivalent and/or a texture class of loamy sand or coarser; ***and***
      ii. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 5 and a chroma of ≤ 2, both moist; ***and***
      iii. ≥ 2.5% *soil organic carbon*;

   and

5. if a layer is present that corresponds to the parent material of the chernic horizon and that has a Munsell colour value of ≤ 4, moist, ≥ 1% (absolute) more *soil organic carbon* than this layer;

   and

6. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50%;

   and

7. a thickness of ≥ 30 cm.

Field identification

A chernic horizon may easily be identified by its blackish colour, caused by the accumulation of organic matter, its well-developed granular or subangular blocky structure, an indication of high base saturation (e.g. pH_{water} > 6), and its thickness.

Relationships with some other diagnostics

The chernic horizon is a special case of the *mollic horizon* with a higher content of *soil organic carbon*, a lower chroma, generally better developed soil structure, a minimum content of fine earth and a greater minimum thickness. The upper limit of the content of *soil organic carbon* is 20%, which is the lower limit for *organic material*.

3.1.7 Cohesic horizon

General description

A cohesic horizon (from Latin *cohaerere*, to stick together) is a subsurface horizon with a massive structure or a weak subangular blocky structure. It is poor in organic matter and iron oxides, normally contains quartz, and the clay fraction is dominated by kaolinite. It is typical for old landscapes of the tropics with a seasonal climate.

Diagnostic criteria

A cohesic horizon consists of *mineral material* and:

1. has < 0.5% *soil organic carbon*; ***and***

2. has ≥ 15% clay; ***and***
3. has a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay; ***and***
4. has, single or in combination, a massive structure or a weak subangular blocky structure; ***and***
5. is not cemented; ***and***
6. has, when dry, a rupture-resistance class of at least hard; ***and***
7. has a thickness of ≥ 10 cm.

Field identification

Cohesic horizons are very resistant to penetration of knife or hammer and have a rupture-resistance class of hard to extremely hard when dry, becoming friable or firm when moist.

Additional information

Cohesic horizons have a porosity low enough to restrict root penetration, but drainage is usually not restricted. The low porosity is attributed to parallel orientation of kaolinite crystals and infilling of voids by clay particles. Usually, they have a bulk density higher than the over- and underlying layers. They are typically found directly below a surface horizon.
Many soils with the cohesic horizon have the Caráter coeso in the Brazilian system and have an apedal B horizon in the South African system. Cohesic horizons may also occur in paleosols.

Relationships with some other diagnostics

Cohesic horizons may coincide with *ferralic* or, less widespread, with *argic horizons*. They differ strongly from *nitic horizons*. Some cohesic horizons show active or relict *stagnic properties* or overlie a *plinthic*, *pisoplinthic* or *petroplinthic horizon*.

3.1.8 Cryic horizon

General description

A cryic horizon (from Greek *kryos*, cold, ice) is a perennially frozen soil horizon in *mineral* or *organic material*.

Diagnostic criteria

A cryic horizon has:
1. continuously for ≥ 2 consecutive years one of the following:
   a. massive ice, cementation by ice or readily visible ice crystals; ***or***
   b. a soil temperature of < 0 °C and insufficient water to form readily visible ice crystals;
   and
2. a thickness of ≥ 5 cm.

Field identification

Cryic horizons occur in areas with permafrost and most of them show evidence of perennial ice segregation. Many of them are overlain by horizons with evidence of cryogenic alteration (mixed soil material, disrupted soil horizons, involutions, organic intrusions, frost heave, separation of coarse fragments from fine earth, cracks). Patterned surface features (earth hummocks, frost mounds, stone circles, stripes, nets and polygons) are common. To identify cryogenic alteration, a soil profile should intersect different elements of patterned ground, if present, or be wider than 2 m.
Soils that contain saline water do not freeze at 0 °C. In order to develop a cryic horizon, such soils must be cold enough to freeze.

Additional information

Permafrost is defined as follows: layer of soil or rock, at some depth beneath the surface, in which the temperature has been continuously below 0 °C for at least some years. It exists where summer heating fails to reach the base of the layer of frozen ground (Arctic Climatology and Meteorology Glossary, National Snow and Ice Data Center, Boulder, USA).
Engineers distinguish between *warm* and *cold* permafrost. *Warm* permafrost has a temperature > -2 °C and has to be considered unstable. *Cold* permafrost has a temperature of ≤ -2 °C and can be used more safely for construction purposes provided the temperature remains under control.

Relationships with some other diagnostics

Cryic horizons may fulfil the diagnostic criteria of *histic*, *folic* or *spodic horizons* and may occur in association with *salic*, *calcic*, *mollic* or *umbric horizons*. In cold arid regions, *yermic properties* may be present.

3.1.9 Duric horizon

General description

A duric horizon (from Latin *durus*, hard) is a subsurface horizon showing nodules or concretions (durinodes), cemented by silica (SiO_2), presumably in the form of opal and microcrystalline silica. Many durinodes have carbonate coatings. It may also contain remnants of a broken-up *petroduric horizon*.

Diagnostic criteria

A duric horizon consists of *mineral material* and has:

1. ≥ 10% (by volume, related to the whole soil) of nodules or concretions (durinodes) and/or of remnants of a broken-up *petroduric horizon* with all of the following:
   a. have ≥ 1% (by exposed area of the nodules or concretions) accumulation of visible secondary silica; ***and***
   b. when air-dry, < 50% (by volume) slake in 1 *M* HCl, even after prolonged soaking, ***and***
   c. when air-dry, ≥ 50% (by volume) slake in hot concentrated KOH or hot concentrated NaOH, at least if alternating with 1 *M* HCl; ***and***
   d. are cemented, at least partially by secondary silica, with a cementation class of at least weakly cemented, both before and after treatment with acid; ***and***
   e. have a diameter of ≥ 1 cm;

   and
2. a thickness of ≥ 10 cm.

Field identification

The identification of secondary silica is described in Annex 1 (Chapter 8.4.27). The durinodes are usually hard (high penetration resistance). Many durinodes are brittle when moist, both before and after treatment with acid.

Additional information

Dry durinodes do not slake appreciably in water, but prolonged soaking can result in the breaking-off of very thin platelets and some slaking. In cross-section, most durinodes are roughly concentric, and concentric stringers of opal may be visible under a hand lens.
If both silica and carbonates are present as cementing agents, the durinodes will only slake if hot concentrated KOH or NaOH (to dissolve the silica) are alternated with HCl (to dissolve the carbontes). If

carbonates are absent, KOH or NaOH alone will be able to slake the durinodes.

Relationships with some other diagnostics

In arid regions, duric horizons occur in association with *gypsic*, *petrogypsic*, *calcic* and *petrocalcic horizons*. A horizon continuously cemented by silica is a *petroduric horizon*.

3.1.10 Ferralic horizon

General description

A ferralic horizon (from Latin *ferrum*, iron, and *alumen*, alum) is a subsurface horizon resulting from long and intense weathering. The clay fraction is dominated by low-activity clays and contains various amounts of resistant minerals such as (hydr-)oxides of Fe, Al, Mn and Ti. There may be a marked residual accumulation of quartz in the silt or sand fractions.

Diagnostic criteria

A ferralic horizon consists of *mineral material* and:

1. has a texture class of sandy loam or finer and ≥ 8% clay; ***and***
2. has < 80% (by volume, related to the whole soil) coarse fragments, *pisoplinthic* concretions or nodules or remnants of a broken-up *petroplinthic horizon*, > 2 mm; ***and***
3. has a CEC (by 1 *M* NH_4OAc, pH 7) of < 16 $cmol_c$ kg^{-1} clay; ***and***
4. has < 10% (by grain count) easily weatherable minerals in the 0.05–0.2 mm fraction; ***and***
5. does not have *andic* or *vitric properties*; ***and***
6. has a thickness of ≥ 30 cm.

Field identification

Ferralic horizons are associated with old and stable landforms. The macrostructure is moderate to weak but typical ferralic horizons have a strong microaggregation.

Ferralic horizons rich in Fe oxides (especially rich in hematite) have usually a friable rupture-resistance class, moist. Disrupted dry soil material flows like flour between the fingers. Lumps of ferralic horizons are usually relatively light in mass because of the low bulk density. Many ferralic horizons give a hollow sound when tapped, indicating high porosity. In some ferralic horizons, the high porosity is the result of termite activity. Generally, the voids between the microaggregates provide a high porosity.

If the ferralic horizon has less hematite and a more yellowish colour, it typically shows a higher bulk density and a lower porosity. It is massive or has a weak subangular blocky structure and a firm rupture-resistance class, moist.

Indicators of clay illuviation such as clay coatings are generally absent or rare, as are pressure faces and other stress features. Boundaries of a ferralic horizon are normally gradual to diffuse, and little variation in colour or particle-size distribution within the horizon can be detected.

Additional information

As an alternative to the weatherable minerals requirement, a total reserve of bases (TRB = exchangeable plus mineral calcium [Ca], magnesium [Mg], potassium [K] and sodium [Na]) of < 25 $cmol_c$ kg^{-1} soil may be indicative.

Ferralic horizons normally have < 10% water-dispersible clay. Occasionally they may have more water-dispersible clay, but if so, they have a ΔpH (pH_{KCl} - pH_{water}) ≥ 0 or a relatively high content of organic carbon.

Examples of easily weatherable minerals are all 2:1 phyllosilicates, chlorites, sepiolites, palygorskites, allophanes, 1:1 trioctahedral phyllosilicates (serpentines), feldspars, feldspathoids, ferromagnesian minerals,

glass, zeolites, dolomite and apatite. The intent of the term weatherable minerals is to include those minerals that are unstable in humid climates compared with other minerals, such as quartz and 1:1 clay minerals, but that are more resistant to weathering than calcite (Soil Survey Staff, 1999).
In thin sections, ferralic horizons have generally an undifferentiated b-fabric due to the isotropic behaviour of Fe oxides. The groundmass has commonly a granular microstructure, with a porosity composed by packing pores and star-like vughs, besides channels and chambers due to a strong bioturbation.

Relationships with some other diagnostics

Some *argic horizons* fulfil all the diagnostic criteria of the ferralic horizon.
Al_{ox}, Fe_{ox}, Si_{ox} in ferralic horizons are very low, which sets them apart from the *nitic horizons* and layers with *andic* or *vitric properties*.
Some *cambic horizons* have a low CEC; however, the amount of weatherable minerals or the TRB is too high for a ferralic horizon. Such horizons represent an advanced stage of weathering and a transition to the ferralic horizon.
Ferralic horizons in freely drained soils of high plateaus and mountains in humid tropical and subtropical regions may occur in association with *sombric horizons*.
Due to redox processes, ferralic horizons may develop into *plinthic horizons*. Most *plinthic horizons* also fulfil the diagnostic criteria of ferralic horizons.

3.1.11 Ferric horizon

General description

A ferric horizon (from Latin *ferrum*, iron) has formed by redox processes, usually caused by stagnant water, which may be active or relict, and shows redoximorphic features. The segregation of Fe (or Fe and Mn) has advanced to such an extent that oximorphic features (coarse masses or discrete concretions and/or nodules) have formed inside soil aggregates, and the matrix between them is largely depleted of Fe and Mn. They do not necessarily have enhanced Fe (or Fe and Mn) contents, but Fe (or Fe and Mn) are concentrated in the oximorphic features. Generally, such segregation leads to poor aggregation of the soil particles in Fe- and Mn-depleted zones and a compaction of the horizon. It mainly occurs in old landscapes.

Diagnostic criteria

A ferric horizon consists of *mineral material* and:

1. consists of one or more subhorizons with one or both of the following:
   a. ≥ 15% of its exposed area occupied by coarse (> 20 mm, average length of the greatest dimension) masses inside soil aggregates that are black or have a Munsell colour hue redder than 7.5YR and a chroma of ≥ 5, both moist; ***or***
   b. ≥ 5% of its exposed area (related to the fine earth plus concretions and/or nodules of any size and any cementation class) occupied by concretions and/or nodules with a cementation class of at least weakly cemented, a reddish and/or blackish colour and a diameter of > 2 mm;

   and
2. does not form part of a *petroplinthic*, *pisoplinthic* or *plinthic horizon*;

   and
3. has a thickness of ≥ 15 cm.

Relationships with some other diagnostics

In tropical or subtropical regions, ferric horizons may grade laterally into *plinthic horizons*. In *plinthic horizons*, the amount of oximorphic features reaches ≥ 15% (by exposed area). Additionally, in *plinthic horizons*, a certain content of Fe_{dith} is exceeded and/or it changes irreversibly to a continuously cemented layer on exposure to repeated drying and wetting with free access of oxygen. If the amount of concretions and/or nodules with a cementation class of at least moderately cemented reaches ≥ 40% (by exposed area), it is a *pisoplinthic horizon*.

3.1.12 Folic horizon

General description

A folic horizon (from Latin *folium*, leaf) consists of well-aerated *organic material*. It develops at the soil surface. In places, it may be covered by *mineral material*. Folic horizons predominantly occur in cool climate or at high elevation.

Diagnostic criteria

A folic horizon consists of *organic material* and:

1. is saturated with water for < 30 consecutive days in most years and is not drained; ***and***
2. has a thickness of ≥ 10 cm.

Relationships with some other diagnostics

The folic horizon has characteristics similar to the *histic horizon*. However, the *histic horizon* forms while saturated with water consecutively for at least 30 days in most years, which causes a completely different vegetation and therefore a different character of the *organic material.*

The *organic material* sets the folic horizon apart from *chernic*, *mollic* or *umbric horizons*, which consist of *mineral material*. Folic horizons may show *andic* or *vitric properties*.

3.1.13 Fragic horizon

General description

A fragic horizon (from Latin *fragilis*, fragile) is a natural, predominantly non-cemented subsurface horizon with large soil aggregates and a porosity pattern such that roots and percolating water penetrate the soil only in between these aggregates. The natural character excludes plough pans and surface traffic pans.

Diagnostic criteria

A fragic horizon consists of *mineral material* and:

1. ≥ 60% (by volume) consist, single or in combination, of prismatic, columnar, angular or subangular blocky soil aggregates that are without coarse roots and that have an average horizontal spacing (aggregate centre to aggregate centre) of ≥ 10 cm; ***and***
2. shows evidence of soil formation as defined in criterion 3 of the *cambic horizon*, at least on the faces of the soil aggregates; ***and***
3. the soil material in between the soil aggregates and ≥ 50% of the volume of the aggregated soil are not cemented; ***and***
4. the non-cemented parts do not cement upon repeated drying and wetting; ***and***
5. the non-cemented aggregated parts have a brittle manner of failure and a rupture-resistance class, moist, of at least firm; ***and***
6. has < 0.5% *soil organic carbon*; ***and***
7. does not show effervescence after adding a 1 *M* HCl solution; ***and***
8. has a thickness of ≥ 15 cm.

Field identification

A fragic horizon has a prismatic and/or blocky structure. In some fragic horizons, the soil aggregates have a

high bulk density. In others, the inner parts of the aggregates may have a relatively high total porosity but, as a result of a dense outer rim, there is no continuity between the pores within and outside the aggregates. Between the prisms or the angular blocks, a weaker aggregate structure or a massive structure and mostly also a lighter soil colour is found. The result is a closed box system with ≥ 60% of the soil volume that cannot be explored by roots and is not percolated by water. Possible reasons for the dense outer rim are: clay coatings, swelling and shrinking, or the pressure of the roots growing only vertically.
It is essential that the required soil volume is inspected from both vertical and horizontal sections; horizontal sections often reveal a polygonal pattern. Three or four such polygons (or a cut up to 1 m^2) are sufficient to test the volumetric basis for the definition of the fragic horizon.
Fragic horizons are commonly loamy, but loamy sand and clay textures are not excluded. In the latter case, the clay mineralogy is dominantly kaolinitic.
The aggregates have commonly a penetration resistance ≥ 4 MPa at field capacity.
The fragic horizon has little faunal activity, except occasionally between the aggregates.

Relationships with some other diagnostics

A fragic horizon may underlie (but not necessarily directly) an *albic, cambic*, *spodic* or *argic horizon*, unless the soil has been truncated. It can overlap partly or completely with an *argic horizon*, and if so, the fragic horizon may show *retic properties* or *albeluvic glossae*. Many fragic horizons have *reducing conditions* and *stagnic properties*.
Contrary to fragic horizons, *plinthic horizons* will cement upon repeated drying and wetting. Contrary to fragic horizons, many other root-restricting horizons are cemented.

3.1.14 Gypsic horizon

General description

A gypsic horizon (from Greek *gypsos*, gypsum) is a non-cemented horizon containing accumulations of secondary gypsum ($CaSO_4 \cdot 2H_2O$) in various forms. It may be a surface or a subsurface horizon.

Diagnostic criteria

A gypsic horizon consists of *mineral material* and:

1. has ≥ 5% gypsum (related to the fine earth plus accumulations of secondary gypsum of any size and any cementation class);
   and
2. has one or both of the following:
   a. meets the diagnostic criteria of *protogypsic properties*; ***or***
   b. a gypsum content of ≥ 5% higher (absolute, related to the fine earth plus accumulations of secondary gypsum of any size and any cementation class) than that of an underlying layer and no *lithic discontinuity* between the two layers;
   and
3. has a product of thickness (in centimetres) times gypsum content (percentage, by mass) of ≥ 150;
   and
4. does not form part of a *petrogypsic horizon*;
   and
5. has a thickness of ≥ 15 cm.

Field identification

How to recognize secondary gypsum is described in Annex 1 (Chapter 8.4.26). The accumulation may be in distinct form or flour-like. The latter gives the gypsic horizon a massive structure.

Gypsum crystals may be visually mistaken for quartz. Gypsum is soft and can easily be scratched with a knife or broken between thumbnail and forefinger. Quartz is hard and cannot be broken except by hammering.

Additional information

The recommended procedure to determine gypsum in the laboratory (Annex 2, Chapter 9.10) also extracts anhydrite, which is considered to be mainly primary.
Thin section analysis is helpful to establish the presence of secondary gypsum, as individual gypsic pedofeatures or as generalized accumulations in the groundmass.
If the accumulation of gypsum becomes such that all or most of the soil structure and/or rock structure disappears and continuous concentrations of gypsum prevail, the Hypergypsic qualifier is used.

Relationships with some other diagnostics

When gypsic horizons become continuously cemented, transition takes place to the *petrogypsic horizon*, the expression of which may be as massive or platy structures. A gypsic horizon and a *petrogypsic horizon* may overlie each other. Accumulations of secondary gypsum, not qualifying for a gypsic horizon, may fulfil the diagnostic criteria of *protogypsic properties*, which are fulfilled by most gypsic horizons as well. *Gypsiric material* includes primary gypsum.
In dry regions, gypsic horizons may be associated with *calcic* and/or *salic horizons*. *Calcic* and gypsic horizons usually occupy distinct positions in the soil profile as the solubility of calcium carbonate is less than that of gypsum. They can normally be distinguished clearly from each other by the morphology (see *calcic horizon*). *Salic* and gypsic horizons also occupy different positions in the profile due to different solubilities.

3.1.15 Histic horizon

General description

A histic horizon (from Greek *histos*, tissue) consists of poorly aerated *organic material*. It develops at the soil surface. In places, it may be covered by *mineral material*.

Diagnostic criteria

A histic horizon consists of *organic material* and:
1. is saturated with water for ≥ 30 consecutive days in most years or is drained; ***and***
2. has a thickness of ≥ 10 cm.

Relationships with some other diagnostics

Histic horizons have characteristics similar to the *folic horizon.* However, the *folic horizon* is consecutively saturated with water for less than thirty days in most years, which causes a completely different vegetation and therefore a different character of the *organic material*. Histic horizons may show *andic* or *vitric properties*.

3.1.16 Hortic horizon

General description

A hortic horizon (from Latin *hortus*, garden) is a mineral surface horizon created by the human activities of deep cultivation, intensive fertilization and/or long-continued application of human and animal wastes and other organic residues (e.g. manures, kitchen refuse, compost and night soil).

Diagnostic criteria

A hortic horizon is a surface horizon consisting of *mineral material* and has:

1. a Munsell colour value and chroma of ≤ 3, moist; ***and***
2. ≥ 1% *soil organic carbon*; ***and***
3. ≥ 120 mg kg^{-1} P in the Mehlich-3 extract in the upper 20 cm; ***and***
4. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50%; ***and***
5. ≥ 25% (by exposed area, weighted average) of animal pores, coprolites or other traces of soil animal activity; ***and***
6. a thickness of ≥ 20 cm.

Field identification

The hortic horizon is thoroughly mixed. Potsherds and other *artefacts* are common, although often abraded. Tillage marks or evidence of mixing of the soil can be present.

Additional information

120 mg kg^{-1} P in the Mehlich-3 extract roughly correspond to 43.6 mg kg^{-1} P or 100 mg kg^{-1} P_2O_5 in the Olsen extract (Kabała et al., 2018), which was the requirement in former editions of WRB.

Relationships with some other diagnostics

Some hortic horizons may also fulfil the diagnostic criteria of a *pretic*, *terric, mollic* or *chernic horizon*.

3.1.17 Hydragric horizon

General description

A hydragric horizon (from Greek *hydor*, water, and Latin *ager*, field) is a subsurface horizon that results from wet-field cultivation.

Diagnostic criteria

A hydragric horizon consists of *mineral material* and:

1. is overlain by an *anthraquic horizon*;

   and
2. consists of one or more subhorizons and each of them has one or more of the following:
   a. reductimorphic features with a Munsell colour value of ≥ 4 and a chroma of ≤ 2, both moist, around biopore walls;

      or
   b. ≥ 15% (by exposed area, related to the fine earth plus oximorphic features of any size and any cementation class) oximorphic features that:
      i. are predominantly inside soil aggregates; ***and***
      ii. have a Munsell colour hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher, moist, than the surrounding material;

      or
   c. ≥ 15% (by exposed area, related to the fine earth plus oximorphic features of any size and any cementation class) oximorphic features that:
      i. are predominantly on biopore walls and, if soil aggregates are present, predominantly on or adjacent to aggregate surfaces; ***and***
      ii. have a Munsell colour hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher, moist, than the surrounding material;

      or

   d. Fe_{dith} ≥ 1.5 times and/or Mn_{dith} ≥ 3 times that of the weighted average of the puddled layer of the overlying *anthraquic horizon*;

   and
3. has a thickness of ≥ 10 cm.

Field identification

The hydragric horizon occurs below the plough pan of an *anthraquic horizon*. The features listed as part of diagnostic criterion 2 rarely occur altogether in the same subhorizon but are commonly distributed over several subhorizons. Major subhorizons have reductimorphic features in pores with a Munsell colour hue of 2.5Y or yellower and a chroma of ≤ 2, both moist, and/or concentrations of Fe and/or Mn oxides inside soil aggregates as a result of oxidizing conditions. It usually shows grey coatings on soil aggregate surfaces, consisting of clay, fine silt and organic matter.

Additional information

Reduced manganese and/or iron move down slowly through the plough pan of the overlying *anthraquic horizon* into the hydragric horizon; the manganese tending to move further than the iron. Within the hydragric horizon, manganese and iron migrate further into the interiors of the soil aggregates where they are oxidized. In the lower part, subhorizons may be influenced by groundwater.

Relationships with some other diagnostics

The hydragric horizon underlies an *anthraquic horizon*.

3.1.18 Irragric horizon

General description

An irragric horizon (from Latin *irrigare*, to irrigate, and *ager*, field) is a mineral surface horizon that builds up gradually through continuous application of irrigation water with substantial amounts of sediments, often including *artefacts* and a significant amount of organic matter.

Diagnostic criteria

An irragric horizon is a surface horizon consisting of *mineral material* and:

1. has, single or in combination, in ≥ 90% (by volume):
   a. soil aggregate structure; ***or***
   b. cloddy structure or other structural elements created by agricultural practices;

   and
2. has one or both of the following:
   a. a clay content ≥ 10% (relative) and ≥ 3% (absolute) higher than that of the layer directly buried by the irragric horizon; ***or***
   b. a fine clay content ≥ 10% (relative) and ≥ 3% (absolute) higher than that of the layer directly buried by the irragric horizon;

   and
3. has differences in medium sand contents, fine sand contents, very fine sand contents, silt contents, clay contents and carbonate contents of < 20% (relative) or < 4% (absolute) between subhorizons;

   and
4. has both of the following:
   a. ≥ 0.3% *soil organic carbon*; ***and***
   b. a weighted average of ≥ 0.5% *soil organic carbon*;

   and

5. has ≥ 25% (by exposed area, weighted average) of animal pores, coprolites or other traces of soil animal activity;
   and
6. shows evidence that the land surface has been raised;
   and
7. has a thickness of ≥ 20 cm.

Field identification

Soils with an irragric horizon show evidence of surface raising, which may be inferred from either field observations or from historical records. The irragric horizon shows evidence of considerable animal activity. The lower boundary is clear; and irrigation deposits or buried soils may be present below.

Relationships with some other diagnostics

Due to continuous ploughing, irragric horizons lack the continuous stratification of *fluvic material*. Some irragric horizons may also qualify as *mollic* or *umbric horizons*, depending on their base saturation.

3.1.19 Limonic horizon

General description

A limonic horizon (from Greek *leimon*, meadow) develops in layers with *gleyic properties* and oximorphic features. Reduced Fe and/or Mn move upwards with ascending groundwater, are oxidized and accumulate to such an extent that at least some parts of the accumulation zones are cemented. It is traditionally called bog iron.

Diagnostic criteria

A limonic horizon:

1. has ≥ 50% (by exposed area, related to the fine earth plus oximorphic features of any size and any cementation class) oximorphic features that are
   a. black, surrounded by lighter-coloured material, ***or***
   b. have a Munsell colour hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher, moist, than the surrounding material ***or***
   c. have a Munsell colour hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher, moist, than the matrix of the directly underlying layer;
   and
2. the oximorphic features are one or both of the following:
   a. predominantly on (former) biopore walls and, if soil aggregates are or were present, predominantly on or adjacent to (former) aggregate surfaces;
      or
   b. underlain by a layer with ≥ 95% (by exposed area) reductimorphic features that have the following Munsell colours, moist:
      i. a hue of N, 10Y, GY, G, BG, B or PB; ***or***
      ii. a hue of 2.5Y or 5Y and a chroma of ≤ 2;
   and
3. is cemented with a cementation class of at least moderately cemented in ≥ 25% (by volume, related to the fine earth plus oximorphic features of any size and any cementation class);
   and
4. has ≥ 2.5% Fe_{dith} + Mn_{dith}, (related to the fine earth plus oximorphic features of any size and any cementation class);

and
5. has a thickness of ≥ 2.5 cm.

Field identification

Limonic horizons show the typical characteristics of layers with *gleyic properties* and oximorphic features. In addition, they are at least partially cemented.

Relationships with some other diagnostics

Limonic horizons develop in layers with *gleyic properties* and oximorphic features. The process of groundwater ascent may be active or relict. Limonic horizons differ from *tsitelic horizons*, which are non-cemented and, if fine-textured, have a low bulk density. Limonic horizons, especially if with Mn oxides, may resemble *spodic horizons*, but typically lack the Al translocation required for *spodic horizons*. However, limonic horizons may overlap with *spodic horizons*, especially with the lower part of the *spodic horizon*.

3.1.20 Mollic horizon

General description

A mollic horizon (from Latin *mollis*, soft) is a relatively thick, dark-coloured surface horizon with a high base saturation and a moderate to high content of organic matter.

Diagnostic criteria

A mollic horizon is a surface horizon consisting of *mineral material* and has:

1. single or in combination, in ≥ 50% (by volume):
   a. soil aggregate structure with an average aggregate size of ≤ 10 cm; ***or***
   b. cloddy structure or other structural elements created by agricultural practices;
   and
2. ≥ 0.6% *soil organic carbon*;
   and
3. one of the following:
   a. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 3 moist;
      or
   b. all of the following:
      i. a sum of calcium carbonate equivalent and gypsum of ≥ 15 and < 40%; ***and***
      ii. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 3 and a chroma of ≤ 3, both moist; ***and***
      iii. ≥ 1% *soil organic carbon*;
      or
   c. all of the following:
      i. a sum of calcium carbonate equivalent and gypsum of ≥ 40% and/or a texture class of loamy sand or coarser; ***and***
      ii. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 5 and a chroma of ≤ 3, both moist; ***and***
      iii. ≥ 2.5% *soil organic carbon*;
   and
4. if a layer is present that corresponds to the parent material of the mollic horizon and that has a Munsell colour value of ≤ 4, moist, ≥ 0.6% (absolute) more *soil organic carbon* than this layer;
   and

5. a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50% on a weighted average;
   and
6. a thickness of one of the following:
   a. ≥ 10 cm if directly overlying *continuous rock*, *technic hard material* or a *cryic, petrocalcic, petroduric, petrogypsic* or *petroplinthic horizon*; ***or***
   b. ≥ 20 cm.

Field identification

A mollic horizon may easily be identified by its dark colour, caused by the accumulation of organic matter, in most cases a well-developed structure (usually a granular or subangular blocky structure), an indication of high base saturation (e.g. $pH_{water} > 6$), and its thickness.

Relationships with some other diagnostics

The base saturation of ≥ 50% separates the mollic horizon from the *umbric horizon*, which is otherwise similar. The upper limit of the content of *soil organic carbon* is 20%, which is the lower limit for *organic material*.
A special type of mollic horizon is the *chernic horizon*. It requires a higher content of *soil organic carbon*, a lower chroma, a better developed soil structure, a minimum content of fine earth and a greater minimum thickness.
Some *hortic*, *irragric*, *pretic* or *terric horizons* may also qualify as mollic horizons.

3.1.21 Natric horizon

General description

A natric horizon (from Arabic *natroon*, salt) is a dense subsurface horizon with a distinctly higher clay content than in the overlying horizon(s). It has a high content of exchangeable Na and in some cases, a relatively high content of exchangeable Mg.

Diagnostic criteria

A natric horizon consists of *mineral material* and:
1. has a texture class of loamy sand or finer and ≥ 8% clay;
   and
2. one or both of the following:
   a. has an overlying coarser-textured layer with all of the following:
      i. the coarser-textured layer is not separated from the natric horizon by a *lithic discontinuity*; ***and***
      ii. if the coarser-textured layer directly overlies the natric horizon, its lowermost sublayer does not form part of a plough layer; ***and***
      iii. if the coarser-textured layer does not directly overlie the natric horizon, the transitional horizon between the coarser-textured layer and the natric horizon has a thickness of ≤ 15 cm; ***and***
      iv. if the coarser-textured layer has < 15% clay, the natric horizon has ≥ 6% (absolute) more clay; ***and***
      v. if the coarser-textured layer has ≥ 15 and < 50% clay, the ratio of clay in the natric horizon to that of the coarser-textured layer is ≥ 1.4; ***and***
      vi. if the coarser-textured layer has ≥ 50% clay, the natric horizon has ≥ 20% (absolute) more clay;
   or
   b. has evidence of illuvial clay in one or more of the following forms:
      i. clay bridges connecting ≥ 15% of the sand grains; ***or***
      ii. clay coatings covering ≥ 15% of the surfaces of soil aggregates, coarse fragments and/or biopore walls; ***or***

   iii. in thin sections, oriented clay bodies (pure or interlayered with silt layers) that constitute ≥ 1% of the section and that have not been transported laterally after they had been formed; ***or***
   iv. a ratio of fine clay to total clay in the natric horizon greater by ≥ 1.2 times than the ratio in the overlying coarser-textured layer;

   and
3. has one or more of the following:
   a. a columnar or prismatic structure in some part of the horizon;

      or
   b. both of the following:
      i. an angular or subangular blocky structure; ***and***
      ii. penetrations of an overlying coarser-textured layer, in which there are uncoated sand and/or coarse silt grains, extending ≥ 2.5 cm into the natric horizon;

   and
4. has one of the following:
   a. an exchangeable Na percentage (ESP) of ≥ 15 throughout the entire natric horizon or its upper 40 cm, whichever is thinner;

      or
   b. both of the following:
      i. more exchangeable Mg plus Na than Ca plus exchange acidity (buffered at pH 8.2) throughout the entire natric horizon or its upper 40 cm, whichever is thinner; ***and***
      ii. an exchangeable Na percentage (ESP) of ≥ 15 in some subhorizon starting ≤ 50 cm below the upper limit of the natric horizon;

   and
5. has a thickness of one-tenth or more of the thickness of the overlying *mineral material*, if present, and one of the following:
   a. ≥ 7.5 cm (if composed of lamellae: combined thickness within 50 cm of the upper limit of the uppermost lamella) if the natric horizon has a texture class of sandy loam or finer; ***or***
   b. ≥ 15 cm (if composed of lamellae: combined thickness within 50 cm of the upper limit of the uppermost lamella).

Field identification

The colour of many natric horizons ranges from brown to black, especially in the upper part, but lighter colours or yellow to red colours may also be found. The structure is usually coarse columnar or coarse prismatic, in places blocky. Rounded tops of the aggregates are characteristic. In many cases, they are covered by a whitish powder coming from the overlying eluvial horizon.

Both colour and structural characteristics depend on the composition of the exchangeable cations and the soluble salt content in the underlying layers. Often, thick and dark-coloured clay coatings occur, especially in the upper part of the horizon. Many natric horizons have poor soil aggregate stability and very low permeability under wet conditions. When dry, the rupture-resistance class of the natric horizon is at least hard. Soil reaction is commonly strongly alkaline with pH_{water} ≥ 8.5.

Additional information

Another measure to characterize the natric horizon is the sodium adsorption ratio (SAR), which is ≥ 13. The SAR is calculated from soil solution data (Na^+, Ca^{2+}, Mg^{2+} given in $mmol_c$/litre): $SAR = Na^+/[(Ca^{2+} + Mg^{2+})/2]^{0.5}$.

In micromorphological studies, natric horizons have a specific fabric. The low structural stability is shown by a pore system with many vesicles and vughs. Pedofeatures consist of layered silt and clay cappings, coatings and infillings; clay intercalations and fragments of clay coatings in the groundmass, due to partial structure collapse.

Relationships with some other diagnostics

The surface horizon may be rich in organic matter, have a thickness from a few centimetres to > 25 cm and may be a *mollic* or *chernic horizon*. An *albic horizon* may be present between the surface and the natric horizon.
Frequently, a salt-affected layer occurs below the natric horizon. The salt influence may extend into the natric horizon, which then becomes saline as well. Salts present may be chlorides, sulfates or carbonates/bicarbonates.
The high ESP of the humus-illuvial part of the natric horizon separates it from the *sombric horizon*.

3.1.22 Nitic horizon

General description

A nitic horizon (from Latin *nitidus*, shiny) is a clay-rich subsurface horizon. It has moderately to strongly developed blocky structure breaking to polyhedral or flat-edged elements with many shiny pressure faces.

Diagnostic criteria

A nitic horizon consists of *mineral material* and:

1. has ≥ 30% clay;
   and
2. has, single or in combination:
   a. moderate to strong angular or subangular blocky structure, breaking into polyhedral or flat-edged second-level structure with pressure faces (shiny surfaces) at ≥ 25% of the surfaces of the soil aggregates of the second-level structure; ***or***
   b. polyhedral structure with pressure faces (shiny surfaces) at ≥ 25% of the surfaces of the soil aggregates;
   and
3. has all of the following:
   a. ≥ 4% Fe_{dith} ('free iron'); ***and***
   b. ≥ 0.2% Fe_{ox} ('active iron'); ***and***
   c. a ratio between Fe_{ox} and Fe_{dith} of ≥ 0.05;
   and
4. does not form part of a *plinthic horizon*;
   and
5. has a thickness of ≥ 30 cm.

Field identification

A nitic horizon has ≥ 30% clay but may feel loamy. Little difference in clay content compared to the overlying and the underlying horizon and a gradual or diffuse distinctness of the horizon boundaries are typical. Similarly, there is no abrupt colour difference to the horizons directly above and below. The colours are of low value with a hue often 2.5YR, moist, but sometimes redder or yellower. The structure is moderate to strong blocky, breaking into polyhedral or flat-edged elements showing shiny pressure faces. In addition, clay coatings may be found. Nitic horizons do not show *reducing conditions* but may show relict oximorphic features, e.g., concretions and nodules of Fe and Mn oxides.

Additional information

In many nitic horizons, the CEC (by 1 *M* NH_4OAc, pH 7) is < 36 $cmol_c\ kg^{-1}$ clay, or even < 24 $cmol_c\ kg^{-1}$

clay. The sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) is about half of the CEC. The moderate to low CEC reflects the dominance of 1:1 clay minerals (either kaolinite and/or [meta-]halloysite). Many nitic horizons have a ratio of water-dispersible clay to total clay of < 0.1. Through the microscope, the birefringent fabric may be striated. Clay coatings, if present, normally form fine coatings around aggregates or may be incorporated into the matrix.

Relationships with some other diagnostics

The nitic horizon may be considered as a strongly expressed *cambic horizon* with specific properties such as a high amount of oxalate-extractable (active) iron. Nitic horizons may show clay coatings and may satisfy the requirements of an *argic horizon*, although the clay content in the nitic horizon is not much higher than in the overlying horizon. Its mineralogy (kaolinitic/[meta]halloysitic) sets it apart from most *vertic horizons*, which have a dominantly smectitic mineralogy and usually occur in climates with a more pronounced dry season. However, nitic horizons may grade laterally into *vertic horizons* in lower landscape positions. The well-expressed soil structure, the high amount of oxalate-extractable iron, and in some cases, the intermediate CEC in nitic horizons set them apart from *ferralic horizons*. Nitic horizons strongly differ from *cohesic horizons*, which may also be rich in clay. Nitic horizons in freely drained soils of high plateaus and mountains in humid tropical and subtropical regions may occur in association with *sombric horizons*.

3.1.23 Panpaic horizon

General description

A panpaic horizon (from Quechua *p'anpay*, to bury) is a buried mineral surface horizon with a significant amount of organic matter formed before having been buried. It is considered a diagnostic horizon, although the process of burying is a geological process and not a soil-forming process.

Diagnostic criteria

A panpaic horizon is a buried surface horizon consisting of *mineral material* and has:

1. ≥ 0.2% *soil organic carbon*; ***and***
2. a content of *soil organic carbon* ≥ 25% (relative) and ≥ 0.2% (absolute) higher than in the overlying layer; ***and***
3. a *lithic discontinuity* at its upper limit; ***and***
4. a thickness of ≥ 5 cm.

Relationships with some other diagnostics

Some panpaic horizons also meet the criteria of the *chernic*, *mollic* or *umbric horizon*. They differ from the *sombric horizon* that has no *lithic discontinuity* at its upper limit. A panpaic horizon may form part of layers of *fluvic material*.

3.1.24 Petrocalcic horizon

General description

A petrocalcic horizon (from Greek *petros*, rock, and Latin *calx*, lime) is cemented by calcium carbonate and in some places, by magnesium carbonate as well. It is either massive or platy in nature and has a very high penetration resistance.

Diagnostic criteria

A petrocalcic horizon consists of *mineral material* and:

1. has very strong effervescence after adding a 1 *M* HCl solution;

and

2. is cemented, at least partially by secondary carbonates, with a cementation class of at least moderately cemented;

   and

3. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume, related to the whole soil);

   and

4. does not have coarse roots except, if present, along the vertical fractures;

   and

5. has a thickness of one of the following
   a. ≥ 1 cm if it is laminar and rests directly on *continuous rock*; ***or***
   b. ≥ 10 cm.

Field identification

Petrocalcic horizons occur as non-platy calcrete (either massive or nodular) or as platy calcrete, of which the following types are the most common:

Lamellar calcrete: superimposed, separate, petrified layers varying in thickness from a few millimetres to several centimetres. The colour is generally white or pink.

Petrified lamellar calcrete: one or several extremely petrified layers, grey or pink in colour. They are generally more cemented than the lamellar calcrete and very massive (no fine lamellar structures, but coarse lamellar structures may be present).

Non-capillary pores in petrocalcic horizons are filled, and the hydraulic conductivity is moderately slow to very slow.

Relationships with some other diagnostics

In arid regions, petrocalcic horizons may occur in association with *(petro-)duric horizons*, into which they may grade laterally. The cementing agent differentiates petrocalcic and *(petro-)duric horizons*. In petrocalcic horizons, calcium and some magnesium carbonate constitute the main cementing agent while some accessory silica may be present. In *(petro-)duric horizons*, silica is the main cementing agent, with or without calcium carbonate. Petrocalcic horizons also occur in association with *gypsic* or *petrogypsic horizons*. Horizons with a significant accumulation of secondary carbonates without continuous cementation qualify as *calcic horizons*.

3.1.25 Petroduric horizon

General description

A petroduric horizon (from Greek *petros*, rock, and Latin *durus*, hard), also known as duripan (United States) or dorbank (South Africa), is a subsurface horizon, usually reddish or reddish brown in colour, that is cemented mainly by illuvial secondary silica (SiO_2, presumably opal and microcrystalline forms of silica). Calcium carbonate may be present as a supplementary cementing agent.

Diagnostic criteria

A petroduric horizon consists of *mineral material* and:

1. has ≥ 1% (by exposed area, related to the fine earth plus accumulations of secondary silica of any size and any cementation class) accumulation of visible secondary silica;

   and

2. both of the following:
   a. when air-dry, < 50% (by volume) slake in 1 *M* HCl, even after prolonged soaking, ***and***

   b. when air-dry, ≥ 50% (by volume) slake in hot concentrated KOH or hot concentrated NaOH, at least if alternating with 1 *M* HCl;

   and

3. is cemented, at least partially by secondary silica, with a cementation class of at least weakly cemented, both before and after treatment with acid;

   and

4. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume, related to the whole soil);

   and

5. does not have coarse roots except, if present, along the vertical fractures;

   and

6. has a thickness of ≥ 1 cm.

Field identification

The identification of secondary silica is described in Annex 1 (Chapter 8.4.27). Effervescence after applying 1 *M* HCl may take place but is mostly not as vigorous as in *petrocalcic horizons*, which appear similar. In very dry environments, the petroduric horizons commonly are platy. In less dry environments, vertical fractures are more common. It has usually a high penetration resistance.

Additional information

If both silica and carbonates are present as cementing agents, the petroduric horizon will only slake if hot concentrated KOH or NaOH (to dissolve the silica) are alternated with HCl (to dissolve the carbonates). If carbonates are absent, KOH or NaOH alone will be able to slake the petroduric horizon.

Relationships with some other diagnostics

In arid climates, petroduric horizons may occur in association with *petrocalcic horizons*, into which they may grade laterally, and/or occur in conjunction with *calcic* or *gypsic horizons*. Remnants of a petroduric horizon or durinodes constitute a *duric horizon*. Petroduric horizons may develop from volcanic ashes and may be overlain by layers with *andic* or *vitric properties*.

3.1.26 Petrogypsic horizon

General description

A petrogypsic horizon (from Greek *petros*, rock, and *gypsos*, gypsum) is a cemented horizon containing accumulations of secondary gypsum ($CaSO_4 \cdot 2H_2O$).

Diagnostic criteria

A petrogypsic horizon consists of *mineral material* and:

1. has ≥ 40% gypsum (related to the fine earth plus accumulations of secondary gypsum of any size and any cementation class); ***and***
2. has ≥ 1% (by exposed area) visible secondary gypsum; ***and***
3. is cemented, at least partially by secondary gypsum, with a cementation class of at least extremely weakly cemented; ***and***
4. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume, related to the whole soil); ***and***
5. does not have coarse roots except, if present, along the vertical fractures; ***and***
6. has a thickness of ≥ 1 cm.

Field identification

Petrogypsic horizons are cemented, whitish and composed predominantly of gypsum. Old petrogypsic horizons may be capped by a thin, laminar layer of newly precipitated gypsum. How to recognize secondary gypsum is described in Annex 1 (Chapter 8.4.26).

Additional information

The recommended procedure to determine gypsum in the laboratory (Annex 2, Chapter 9.10) also extracts anhydrite, which is considered to be mainly primary.
In thin sections, the petrogypsic horizon shows a a groundmass, composed of interlocked gypsum crystals with a hypidiotopic or xenotopic fabric, mixed with varying amounts of detrital material.

Relationships with some other diagnostics

As the petrogypsic horizon develops from a *gypsic horizon*, the two are closely related. Petrogypsic horizons frequently occur in association with *(petro-)calcic horizons*. Accumulations of calcium carbonate and gypsum usually occupy different positions in the soil profile because the solubility of calcium carbonate is less than that of gypsum. Normally, they can be distinguished clearly from each other by their morphology (see *calcic horizon*).

3.1.27 Petroplinthic horizon

General description

A petroplinthic horizon (from Greek *petros*, rock, and *plinthos*, brick) is a continuous or fractured layer of cemented material, in which Fe (and in some cases also Mn) (hydr-)oxides are an important cement and in which organic matter is either absent or present only in traces. It has formed by continuous cementation of a *plinthic* or *pisoplinthic horizon*. Advanced crystallization of the oxides causes a very high penetration resistance. Traditional names for horizons similar to the petroplinthic horizon are 'laterite' or 'ironstone'.

Diagnostic criteria

A petroplinthic horizon consists of *mineral material* and:

1. consists of oximorphic features inside (former) soil aggregates that are at least partially interconnected and have a reddish, yellowish and/or blackish colour;
   and
2. has one or both of the following:
   a. ≥ 2.5% Fe_{dith} (related to the fine earth plus oximorphic features of any size and any cementation class);
      or
   b. ≥ 10% Fe_{dith} in the oximorphic features;
   and
3. has a ratio between Fe_{ox} and Fe_{dith} of < 0.1 in the fine earth or in the oximorphic features;
   and
4. is cemented with a cementation class of at least strongly cemented;
   and
5. is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume, related to the whole soil);
   and
6. does not have coarse roots except, if present, along the vertical fractures;
   and
7. has a thickness of ≥ 10 cm.

Field identification

Petroplinthic horizons are extremely hard (high penetration resistance) and typically rusty brown to yellowish brown. They are either massive or show an interconnected nodular pattern that encloses material with a lower penetration resistance. They may be fractured. Roots are generally found only in vertical fractures. Penetretation resistance is ≥ 4.5 MPa in ≥ 50% of the volume of the fine earth. From this value upwards, the rupture resistance will not sink upon wetting (see Asiamah, 2000).

Additional information

The ratio between Fe_{ox} and Fe_{dith} has been estimated from data given by Varghese & Byju (1993).

Relationships with some other diagnostics

Petroplinthic horizons are closely associated with *plinthic* and *pisoplinthic horizons* from which they develop. In some places, *plinthic horizons* can be traced by following petroplinthic layers that have formed, for example, in road cuts.
The low ratio between Fe_{ox} and Fe_{dith} separates the petroplinthic horizon from cemented *spodic horizons* (Ortsteinic or Placic qualifiers), which in addition contain mostly a fair amount of organic matter. *Limonic horizons* also have higher ratios.

3.1.28 Pisoplinthic horizon

General description

A pisoplinthic horizon (from Latin *pisum*, pea, and Greek *plinthos*, brick) contains a large amount of concretions and/or nodules that are at least moderately cemented by Fe (and in some cases also by Mn) (hydr-)oxides. It may also contain remnants of a broken-up *petroplinthic horizon*.

Diagnostic criteria

A pisoplinthic horizon consists of *mineral material* and:

1. has ≥ 40% of its volume (related to the whole soil) occupied by, single or in combination,
   a. yellowish, reddish and/or blackish concretions and/or nodules; ***or***
   b. remnants of a broken-up *petroplinthic horizon,*

   with a diameter of > 2 mm and a cementation class of at least moderately cemented;
   and
2. does not form part of a *petroplinthic horizon*;
   and
3. has a thickness of ≥ 15 cm.

Relationships with some other diagnostics

A pisoplinthic horizon results, when discrete concretions and/or nodules of a *plinthic horizon* reach a certain percentage and a cementation class of at least moderately cemented. The cementation class and the amount of concretions and/or nodules separate it from the *ferric horizon*. If the concretions and/or nodules are sufficiently interconnected, the pisoplinthic horizon becomes a *petroplinthic horizon*. A pisoplinthic horizon may also be formed by the fracturing of a *petroplinthic horizon*.

3.1.29 Plaggic horizon

General description

A plaggic horizon (from Low German *plaggen*, sod) is a black or brown mineral surface horizon that results from human activity. Mostly in nutrient-poor soils in the north-western part of Central Europe from

Medieval times until the introduction of mineral fertilizers at the beginning of the 20th century, sod and other topsoil materials were commonly used for bedding livestock. The sods consist of grassy, herbaceous or dwarf-shrub vegetation, its root mats and organic and mineral soil sticking to them. The mixture of sods and excrements was later spread on fields. The material brought in eventually produced an appreciably thickened horizon (in places > 100 cm thick) that is rich in *soil organic carbon*. Base saturation is typically low.

Diagnostic criteria

A plaggic horizon is a surface horizon consisting of *mineral material* and:

1. has a texture class of sand, loamy sand, sandy loam or loam, or a combination of them;
   and
2. one or more of the following:
   a. contains *artefacts,* but < 20% (by volume, related to the whole soil); ***or***
   b. has ≥ 100 mg kg^{-1} P in the Mehlich-3 extract in the upper 20 cm; ***or***
   c. has in its lower part spade or hook marks, remnants of a plough layer or other evidence of former agricultural activity;

   and
3. has a Munsell colour value of ≤ 4 moist, and ≤ 5 dry, and a chroma of ≤ 4 moist;
   and
4. has ≥ 0.6% *soil organic carbon*;
   and
5. has a base saturation (by 1 *M* NH_4OAc, pH 7) of < 50%, unless the soil has been limed or received mineral fertilizers;
   and
6. shows evidence that the land surface has been raised;
   and
7. has a thickness of ≥ 20 cm.

Field identification

The plaggic horizon has brownish or blackish colours, related to the origin of source materials. It may contain *artefacts*, but less than 20%. Its reaction is mostly slightly to strongly acid. The pH may have risen due to recent liming but seldom reaching a high base saturation. It may show evidence of old agricultural operations in its lower part, such as spade or hook marks as well as old plough layers. Plaggic horizons commonly overlie buried soils although the original surface layers may be mixed with the plaggen. In some cases, ditches have been made in the buried soil as a cultivation mode for soil improvement. The lower boundary is typically clear to abrupt.

Additional information

The texture class is in most cases sand or loamy sand. Sandy loam and loam are rare. The *soil organic carbon* may include carbon added with the plaggen. 100 mg kg^{-1} P in the Mehlich-3 extract (same value as for *pretic horizons*) roughly correspond to 143 mg kg^{-1} P or 327 mg kg^{-1} P_2O_5 in 1% citric acid (Kabała et al., 2018). Originally, the plaggic horizon has a low base saturation. If limed or fertilized, this criterion is waived.

Relationships with some other diagnostics

After liming, some plaggic horizons may fulfil the criteria of the *terric horizon*, but t*erric horizons* usually have a higher animal activity. Some plaggic horizons may contain black carbon and also fulfil the criteria of the *pretic horizon*. Some plaggic horizons may also qualify as *umbric* or even as *mollic horizon*.

3.1.30 Plinthic horizon

General description

A plinthic horizon (from Greek *plinthos*, brick) is a subsurface horizon that is rich in Fe (in some cases also Mn) (hydr-)oxides and poor in humus. The clay fraction is dominated by kaolinite, together with other products of strong weathering, such as gibbsite. It may contain quartz. The plinthic horizon has formed by redox processes, usually caused by stagnant water, which may be active or relict, and shows redoximorphic features. The plinthic horizon is not continuously cemented. On exposure to repeated drying and wetting with free access to oxygen, the oxides become more crystallized leading to a continuously cemented horizon.

Diagnostic criteria

A plinthic horizon consists of *mineral material* and:

1. has in ≥ 15% of its exposed area (related to the fine earth plus oximorphic features of any size and any cementation class) oximorphic features inside (former) soil aggregates that are black or have a redder hue and a higher chroma than the surrounding material;
   and
2. one or more of the following:
   a. has ≥ 2.5% Fe_{dith} (related to the fine earth plus oximorphic features of any size and any cementation class); ***or***
   b. has ≥ 10% Fe_{dith} in the oximorphic features; ***or***
   c. changes irreversibly to a continuously cemented horizon with a cementation class of at least strongly cemented after repeated drying and wetting;
   and
3. has a ratio between Fe_{ox} and Fe_{dith} of < 0.1 in the fine earth or in the oximorphic features;
   and
4. does not form part of a *petroplinthic* or *pisoplinthic horizon*;
   and
5. has a thickness of ≥ 15 cm.

Field identification

A plinthic horizon shows prominent redoximorphic features. In a perennially moist soil, many of the oximorphic features are non-cemented or have a low cementation class and can be cut with a spade.

Additional information

Micromorphological studies may reveal the extent of impregnation of the soil mass by Fe (hydr-)oxides. In many plinthic horizons, prolonged *reducing conditions* are not present anymore.

Relationships with some other diagnostics

If the concretions and nodules of the plinthic horizon become at least moderately cemented and reach ≥ 40% of the exposed area, the plinthic horizon becomes a *pisoplinthic horizon*. If the plinthic horizon becomes continuously cemented, the plinthic horizon becomes a *petroplinthic horizon*.
If the oximorphic features do not reach 15% of the exposed area, it may be a *ferric horizon*.

3.1.31 Pretic horizon

General description

A pretic horizon (from Portuguese *preto*, black) is a mineral surface horizon that results from human activities with the addition of black carbon, especially charcoal. It is characterized by its dark colour, usually

the presence of *artefacts* (ceramic fragments, lithic instruments, bone or shell tools etc.) and high contents of organic carbon, phosphorus, calcium, magnesium and micronutrients (mainly zinc and manganese), usually contrasting with natural soils in the surrounding area. It contains remnants of black carbon, which may be recognized visually or by chemical analyses.
Pretic horizons are for example widespread in the Amazon Basin, where they are the result of pre-Columbian activities and have persisted over many centuries despite the prevailing humid tropical conditions generally causing high organic matter mineralization rates. These soils with a pretic horizon are known as 'Terra Preta de Indio' or 'Amazonian Dark Earths'. They generally have high organic carbon stocks. Many of them are dominated by low-activity clays.

Diagnostic criteria

A pretic horizon is a surface horizon consisting of *mineral material* and has:

1. a Munsell colour value of ≤ 4 and a chroma of ≤ 3, both moist;
   and
2. ≥ 0.6% *soil organic carbon*;
   and
3. exchangeable Ca plus Mg (by 1 *M* NH_4OAc, pH 7) of ≥ 1 $cmol_c\ kg^{-1}$ fine earth;
   and
4. ≥ 100 mg kg^{-1} P in the Mehlich-3 extract;
   and
5. one or both of the following:
   a. ≥ 1% (by exposed area, related to the fine earth plus black carbon of any size) visible black carbon;
      or
   b. both of the following
      i. ≥ 0.3% carbon belonging to molecules of black carbon, determined by chemical analyses; ***and***
      ii. a ratio between carbon belonging to molecules of black carbon and total organic carbon of ≥ 0.15, determined by chemical analyses;

   and
6. one or more layers with a combined thickness of ≥ 20 cm.

Additional information

Black carbon is an *artefact* only if it is intentionally manufactured by humans. The minimum *soil organic carbon* content (criterion 2) must be fulfilled without the *artefacts*.
P in the Mehlich-3 extract roughly is the double of the values obtained in the Mehlich-1 extract (Kabała et al., 2018), which was the requirement in the 3rd edition of WRB. Additionally, compared to the 3rd edition, the value was increased from 30 to 50 (Mehlich-1) or from 60 to 100 (Mehlich-3) mg kg^{-1}.

Relationships with some other diagnostics

Some pretic horizons may also fulfil the criteria of the *plaggic horizon* and, especially in their upper parts, the criteria of the *hortic horizon*. Some pretic horizons may qualify as *mollic* or *umbric horizons*. Old charcoal hearths usually fail the P criterion of the pretic horizon. They do not fit into the concept of the pretic horizon, are characterized by the Carbonic and the Pyric qualifier, and many of them are Technosols.

3.1.32 Protovertic horizon

General description

A protovertic horizon (from Greek *proton*, first, and Latin *vertere,* to turn) has swelling and shrinking clay minerals.

Diagnostic criteria

A protovertic horizon consists of *mineral material* and has:

1. ≥ 30% clay;

   and
2. one or more of the following:
   a. wedge-shaped soil aggregates in ≥ 10% (by volume); ***or***
   b. slickensides on ≥ 5% of the surfaces of soil aggregates; ***or***
   c. *shrink-swell cracks*; ***or***
   d. a coefficient of linear extensibility (COLE) of ≥ 0.06;

   and
3. a thickness of ≥ 15 cm.

Field identification

Wedge-shaped soil aggregates and slickensides (see Annex 1, Chapter 8.4.10 and 8.4.14) may not be immediately evident if the soil is moist. A decision about their presence can sometimes only be made after the soil has dried out. Wedge-shaped aggregates may be a second-level structure of larger angular blocky or prismatic elements, which should be carefully examined to see if wedge-shaped aggregates are present.

Relationships with some other diagnostics

If the swelling and shrinking is more prominent (or the layer is thicker) the protovertic horizon grades into a *vertic horizon*.

3.1.33 Salic horizon

General description

A salic horizon (from Latin *sal*, salt) is a surface horizon or a subsurface horizon at a shallow depth that contains high amounts of readily soluble salts, i.e. salts more soluble than gypsum ($CaSO_4 \cdot 2H_2O$; log Ks = -4.85 at 25 °C).

Diagnostic criteria

A salic horizon has:

1. at some time of the year
   a. if the pH_{water} of the saturation extract is ≥ 8.5, an electrical conductivity of the saturation extract (EC_e) of ≥ 8 dS m^{-1} measured at 25 °C ***and*** a product of thickness (in centimetres) and EC_e (in dS m^{-1}) of ≥ 240; ***or***
   b. an electrical conductivity of the saturation extract (EC_e) of ≥ 15 dS m^{-1} measured at 25 °C ***and*** a product of thickness (in centimetres) and EC_e (in dS m^{-1}) of ≥ 450;

   and
2. a thickness of ≥ 15 cm (combined thickness if there are superimposed subhorizons meeting criteria 1.a and 1.b).

Field identification

Halophytes (e.g. some species of *Salicornia*, *Tamarix* and *Suaeda*) and salt-tolerant crops are first indicators. Salt-affected layers are often puffy. Salts precipitate only after evaporation of most soil moisture; if the soil is moist, salt may not be visible.
Salts may precipitate at the soil surface (external Solonchaks) or at depth (internal Solonchaks). A salt crust,

if present, may be part of the salic horizon.

Additional information

In alkaline carbonate soils, an EC_e at 25 °C of ≥ 8 dS m^{-1} and a pH_{water} of ≥ 8.5 are very common. Salic horizons may consist of *organic* or *mineral material*.

3.1.34 Sombric horizon

General description

A sombric horizon (from French *sombre*, dark) is a dark-coloured subsurface horizon containing more organic matter than the directly overlying horizon. It has no lithic discontinuity at its upper limit and is neither associated with Al nor dispersed by Na.

Diagnostic criteria

A sombric horizon consists of *mineral material* and:

1. has ≥ 0.2% *soil organic carbon*; ***and***
2. has a content of *soil organic carbon* ≥ 25% (relative) and ≥ 0.2% (absolute) higher than in the overlying layer; ***and***
3. does not have a *lithic discontinuity* at its upper limit and does not form part of a *natric* or *spodic horizon*; ***and***
4. has a thickness of ≥ 10 cm.

Field identification

Sombric horizons are found in dark-coloured subsoils, in many cases associated with well-drained soils of high plateaus and mountains in humid tropical and subtropical regions. They resemble buried horizons but, in contrast to many of these, sombric horizons more or less follow the shape of the soil surface. They have a lower Munsell colour value than the directly overlying horizon and commonly a low base saturation.

Additional information

There are two important theories about the genesis of sombric horizons (de Almeida et al., 2015).
First theory: The higher content of organic matter is illuvial, but neither associated with Al nor with Na. In this case, coatings of organic matter at soil aggregate surfaces and pore walls as well as illuvial organic matter in thin sections are found.
Second theory: The higher content of organic matter is residual. A moister climate and a higher plant biomass (e.g. forest) formed thick A horizons. Afterwards, climate became drier, the upper part of the old A horizon underwent an intense mineralization, while the residues of the current vegetation, poorer in biomass (e.g. savanna), form only a thin A horizon. At greater depth, mineralization is slower, and the lower part of the old A horizon is preserved, especially if climate is cool and base saturation low.

Relationships with some other diagnostics

Sombric horizons may coincide with *argic*, *cambic*, *ferralic* or *nitic horizons*. Contrary to *panpaic horizons*, sombric horizons have no *lithic discontinuity* at their upper limit. *Spodic horizons* are differentiated from sombric horizons by their much higher CEC of the clay fraction. The humus-illuvial part of *natric horizons* has a higher clay content, a high Na saturation and a specific structure, which separates them from sombric horizons.

3.1.35 Spodic horizon

General description

A spodic horizon (from Greek *spodos*, wood ash) is a subsurface horizon that contains illuvial substances. In most spodic horizons, the appearance of the upper subhorizons is characterized by dark illuvial organic matter and that of the lower subhorizons by intensely coloured illuvial Fe oxides. Some spodic horizons, however, show either little illuviation of Fe or little illuviation of organic matter. In all spodic horizons, illuviated Al can be proven analytically. The illuvial materials are characterized by a high pH-dependent charge, a relatively large surface area and an elevated water retention. An overlying eluvial horizon may intrude with tongues into the spodic horizon.

Diagnostic criteria

A spodic horizon consists of *mineral material* and:

1. has a pH (1:1 in water) of < 5.9, unless the soil has been limed or fertilized;
   and
2. has a subhorizon with an Al_{ox} value that is ≥ 1.5 times that of the lowest Al_{ox} value of all the mineral layers above the spodic horizon;
   and
3. has in its uppermost 1 cm one or both of the following:
   a. ≥ 0.5% *soil organic carbon*; ***or***
   b. a Munsell colour chroma of ≥ 6, moist, in ≥ 90% of its exposed area;
   and
4. has one or more subhorizons with the following Munsell colours, moist, in ≥ 90% of their exposed area:
   a. a hue of 5YR or redder; ***or***
   b. a hue of 7.5YR and a value of ≤ 5; ***or***
   c. a hue of 10YR and a value and a chroma of ≤ 2; ***or***
   d. a hue of 10YR and a chroma of ≥ 6; ***or***
   e. a colour of 10YR 3/1; ***or***
   f. a hue of N and a value of ≤ 2;
   and
5. one or more of the following:
   a. is overlain by *claric material* that is not separated from the spodic horizon by a *lithic discontinuity* and that overlies the spodic horizon either directly or above a transitional horizon that has a thickness of one-tenth or less of the overlying *claric material*; ***or***
   b. ≥ 10% of the sand grains of the horizon show cracked coatings; ***or***
   c. has a subhorizon that is cemented with a cementation class of at least weakly cemented in ≥ 50% of its horizontal extension; ***or***
   d. has a subhorizon with an Al_{ox} + ½Fe_{ox} value of ≥ 0.5% that is ≥ 2 times that of the lowest Al_{ox} + ½Fe_{ox} value of all the mineral layers above the spodic horizon;
   and
6. does not form part of a *natric horizon*;
   and
7. has a thickness of ≥ 2.5 cm.

Field identification

Many spodic horizons underly *claric material* and have brownish-black to reddish-brown colours, which often fade downwards. The shape of many spodic horizons is wavy, irregular, or broken. Spodic horizons may be (partially) cemented. Thin and relatively continuous cementations are indicated by the Placic qualifier and thicker and/or less continuous cementations by the Ortsteinic qualifier. Spodic horizons may extend further down in ribbon-like accumulations, which are not included in the calculation of the minimum thickness.

Relationships with some other diagnostics

There may be a *hortic*, *plaggic*, *terric* or *umbric horizon* above the spodic horizon, with or without *claric material* in between.
Spodic horizons in volcanic materials may exhibit *andic properties* as well. Spodic horizons in other materials may exhibit some characteristics of the *andic properties*, but normally have a higher bulk density. For classification purposes, the presence of a spodic horizon, unless buried deeper than 50 cm, is given preference over the occurrence of *andic properties*.
Some layers with *andic properties* resemble spodic horizons, if they are covered by relatively young, light-coloured volcanic ejecta that satisfy the requirements of *claric material*. There is a *lithic discontinuity* in between, which excludes them from being spodic horizons. This can be further proven by the following analyses: The uppermost 2.5 cm of the spodic horizon have a C_{py}/OC and a C_f/C_{py} of ≥ 0.5. C_{py}, C_f and OC are pyrophosphate-extractable C, fulvic acid C and organic C, respectively (Ito et al*.,* 1991).
Limonic and *tsitelic horizons* may resemble spodic horizons, but lack the translocation of Al. However, *limonic horizons* may overlap with spodic horizons, especially with the lower part of the spodic horizon.
Similar to many spodic horizons, *sombric horizons* also contain more organic matter than an overlying layer. They can be differentiated from each other by the clay mineralogy. Kaolinite usually dominates in *sombric horizons*, whereas the clay fraction of spodic horizons commonly contains significant amounts of vermiculite and Al-interlayered chlorite.
Plinthic horizons, which contain large amounts of accumulated Fe, have less Fe_{ox} than spodic horizons.

3.1.36 Terric horizon

General description

A terric horizon (from Latin *terra*, earth) is a mineral surface horizon that develops through addition of *mineral material* or a combination of *mineral material* and organic residues, for example, fertile mineral soil, compost, calcareous beach sands, loess or mud. It may contain stones, randomly sorted and distributed. In most cases, it is built up gradually over a long period of time. Occasionally, terric horizons are created by single additions of material. Normally the added material is mixed with the original topsoil.

Diagnostic criteria

A terric horizon is a surface horizon consisting of *mineral material* and:

1. shows evidence of addition of material substantially different from the environment, where it has been placed; ***and***
2. contains, if any, < 10% (by volume, related to the whole soil) *artefacts*; ***and***
3. has ≥ 0.6% *soil organic carbon*; ***and***
4. has a base saturation (by 1 *M* NH_4OAc, pH 7) of ≥ 50%; ***and***
5. shows evidence that the land surface has been raised; ***and***
6. has a thickness of ≥ 20 cm.

Field identification

Terric horizons show characteristics related to the source material, e.g. in colour. Buried soils may be observed at the base of the horizon although mixing can obscure the contact. Soils with a terric horizon show a raised surface that may be inferred either from field observation or from historical records. The terric horizon is not homogeneous, but subhorizons are thoroughly mixed. It commonly contains a small amount of *artefacts* such as pottery fragments, cultural debris and refuse, that are typically very small (< 1 cm in diameter) and very abraded.

Relationships with some other diagnostics

Some terric horizons may also fulfil the criteria of anthropogenic horizons with stronger alterations, like the *hortic*, *plaggic* or the *pretic horizon*. Most *hortic horizons* show more and most *plaggic horizons* less soil animal activity than the terric horizon. The *pretic horizons* contain black carbon. Some terric horizons may qualify as *mollic* horizon.

3.1.37 Thionic horizon

General description

A thionic horizon (from Greek *theion*, sulfur) is an extremely acid subsurface horizon in which sulfuric acid is formed through oxidation of sulfides.

Diagnostic criteria

A thionic horizon has:

1. a pH (1:1 by mass in water, or in a minimum of water to permit measurement) of < 4;
   and
2. one or more of the following:
   a. accumulations of iron or aluminium sulfate or hydroxysulfate minerals, predominantly on or adjacent to surfaces of soil aggregates; ***or***
   b. direct superposition on *sulfidic material*; ***or***
   c. ≥ 0.05% water-soluble sulfate;
   and
3. a thickness of ≥ 15 cm.

Field identification

Thionic horizons generally exhibit pale yellow jarosite or yellowish-brown schwertmannite accumulations on or adjacent to surfaces of soil aggregates. Soil reaction is extremely acid; pH_{water} of 3.5 is quite common. While mostly associated with recent sulfidic coastal sediments, thionic horizons may also develop inland in *sulfidic materials* that may be present either in natural deposits or in *artefacts* such as mine spoil.

Additional information

Iron or aluminium sulfate or hydroxysulfate minerals include jarosite, natrojarosite, schwertmannite, sideronatrite and tamarugite. Thionic horizons may consist of *organic* or *mineral material*.

Relationships with some other diagnostics

A thionic horizon often underlies a horizon with strongly expressed *stagnic properties*.

3.1.38 Tsitelic horizon

General description

A tsitelic horizon (from Georgian *tsiteli*, red) shows a lateral accumulation of Fe. It is usually found on lower slopes or in depressions. Stagnosols and Planosols occur upslope in inclined positions and have lost reduced Fe by lateral subsurface water flow. Further down, the reduced Fe gets in contact with atmospheric oxygen, is oxidized and accumulates in subsurface horizons starting usually at shallow depths. They are rich in oxalate-extractable Fe, which gives the tsitelic horizons a homogeneous reddish colour.

Diagnostic criteria

A tsitelic horizon consists of *mineral material* and
1. has ≥ 1% Fe_{ox}; ***and***
2. has a ratio between Fe_{ox} and Fe_{dith} of ≥ 0.5; ***and***
3. has $Al_{ox} < Fe_{ox}$; ***and***
4. has a Munsell colour chroma of ≥ 4, moist; ***and***
5. does not show reductimorphic features; ***and***
6. does not form part of a *limonic* or *spodic horizon*; ***and***
7. has a thickness of ≥ 5 cm.

Field identification

The accumulation of ferrihydrites causes a homogeneous reddish colour and, if the horizon is fine-textured, a low bulk density and some thixotropy.

Relationships with some other diagnostics

Tsitelic horizons may resemble *spodic horizons* of Rustic Podzols but lack the translocation of Al that is required for *spodic horizons*. If showing low bulk density and thixotropy, they may give the impression of *andic properties*, but they have neither a significant amount of allophanes and imogolites nor of Al-humus complexes. Contrary to most horizons with *andic properties*, tsitelic horizons show more Fe than Al in the oxalate extract. Layers with oximorphic features caused by *gleyic properties* may also look similar to tsitelic horizons. While in layers with *gleyic properties*, the oxides are predominantly found at soil aggregate surfaces, the oxides in tsitelic horizons fill the entire soil matrix homogeneously. Tsitelic horizons distinguish well from *limonic horizons*, which are (at least partially) cemented.

3.1.39 Umbric horizon

General description

An umbric horizon (from Latin *umbra*, shade) is a relatively thick, dark-coloured surface horizon with a low base saturation and a moderate to high content of organic matter.

Diagnostic criteria

An umbric horizon is a surface horizon consisting of *mineral material* and has:
1. single or in combination, in ≥ 50% (by volume):
   a. soil aggregate structure with an average aggregate size of ≤ 10 cm; ***or***
   b. cloddy structure or other structural elements created by agricultural practices;
   and
2. ≥ 0.6% *soil organic carbon*;
   and
3. one or both of the following:
   a. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 3 moist;
   or
   b. all of the following:
      i. a texture class of loamy sand or coarser; ***and***
      ii. in ≥ 90% of the exposed area of the entire horizon or of the subhorizons below any plough layer, a Munsell colour value of ≤ 5 and a chroma of ≤ 3, both moist; ***and***
      iii. ≥ 2.5% *soil organic carbon*;

and

4. if a layer is present that corresponds to the parent material of the umbric horizon and that has a Munsell colour value of ≤ 4, moist, ≥ 0.6% (absolute) more *soil organic carbon* than this layer;

   and

5. a base saturation (by 1 *M* NH_4OAc, pH 7) of < 50% on a weighted average;

   and

6. a thickness of one of the following:
   a. ≥ 10 cm if directly overlying *continuous rock*, *technic hard material* or a *cryic*, *petroduric* or *petroplinthic horizon*; ***or***
   b. ≥ 20 cm.

Field identification

The main field characteristics of an umbric horizon are its dark colour and its structure. In general, umbric horizons tend to have a lesser grade of soil structure than *mollic horizons*.
Most umbric horizons have an acid reaction (pH_{water} < 5.5), which usually indicates a base saturation of < 50%. An additional indication for strong acidity is a shallow, horizontal rooting pattern in the absence of a physical barrier.

Relationships with some other diagnostics

The base saturation requirement sets the umbric horizon apart from the *mollic horizon*, which is otherwise similar. The upper limit of the content of *soil organic carbon* is 20%, which is the lower limit for *organic material*.
Some *irragric* and *plaggic horizons* may also qualify as umbric horizons.

3.1.40 Vertic horizon

General description

A vertic horizon (from Latin *vertere*, to turn) is a clay-rich subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped soil aggregates.

Diagnostic criteria

A vertic horizon consists of *mineral material* and has:

1. ≥ 30% clay;

   and

2. one or both of the following:
   a. in ≥ 20% (by volume), wedge-shaped soil aggregates with a longitudinal axis tilted between ≥ 10° and ≤ 60° from the horizontal; ***or***
   b. slickensides on ≥ 10% of the surfaces of soil aggregates;

   and

3. *shrink-swell cracks*;

   and

4. a thickness of ≥ 25 cm.

Field identification

Vertic horizons are clay-rich and, when dry, often have a rupture-resistance class of at least hard. Polished, shiny surfaces with striations (slickensides), often at sharp angles, are distinctive.
Wedge-shaped soil aggregates and slickensides (see Annex 1, Chapter 8.4.10 and 8.4.14) may not be immediately evident if the soil is moist. A decision about their presence can sometimes only be made after

the soil has dried out. Wedge-shaped aggregates may be a second-level structure of larger angular blocky or prismatic elements, which should be carefully examined to see if wedge-shaped aggregates are present.

Additional information

The coefficient of linear extensibility (COLE, see Annex 2, Chapter 9.6) is usually ≥ 0.06.

Relationships with some other diagnostics

Several other diagnostic horizons may also have high clay contents, e.g., the *argic*, *natric* and *nitic horizon*. Most of them lack the characteristics typical for the vertic horizon. However, they may be laterally linked in the landscape with vertic horizons, the latter usually taking up the lowest position. Less pronounced swelling and shrinking of clay minerals leads to a *protovertic horizon*.

3.2 Diagnostic properties

Diagnostic properties are characterized by a combination of attributes that reflect results of soil-forming processes or indicate specific conditions of soil formation. Their features can be observed or measured in the field or the laboratory and require a minimum or maximum expression to qualify as diagnostic. A minimum thickness is not part of the criteria.

3.2.1 Abrupt textural difference

General description

An abrupt textural difference (from Latin *abruptus*, broken away) is a very sharp increase in clay content within a limited depth range.

Diagnostic criteria

An abrupt textural difference refers to two superimposed layers consisting of *mineral material* with all of the following:

1. the underlying layer has all of the following:
   a. ≥ 15% clay; ***and***
   b. a thickness of ≥ 7.5 cm;
   and
2. the underlying layer starts ≥ 10 cm from the mineral soil surface;
   and
3. the underlying layer has, compared to the overlying layer:
   a. at least twice as much clay if the overlying layer has < 20% clay; ***or***
   b. ≥ 20% (absolute) more clay if the overlying layer has ≥ 20% clay;
   and
4. if the limit between the two layers is not even, the depth of the abrupt textural difference is where the underlying layer reaches ≥ 50% of the total volume;
   and
5. a transitional layer, if present, has a thickness of ≤ 2 cm.

Additional information

An example for an uneven limit between the two layers are *retic properties* in the underlying layer. Depending on the development of the *retic properties*, the abrupt textural difference may be at the upper limit of the *retic properties* or further down (criterion 3).

3.2.2 Albeluvic glossae

General description

The term albeluvic glossae (from Latin *albus*, white, and *eluere*, to wash out, and Greek *glossa*, tongue) refers to penetrations of clay- and Fe-depleted material into an *argic horizon*. Albeluvic glossae occur along soil aggregate surfaces and form vertically continuous tongues. In horizontal sections, they exhibit a polygonal pattern.

Diagnostic criteria

Albeluvic glossae:

1. refer to an *argic horizon* and, if the *argic horizon* is < 30 cm thick, also to the underlying layers until 30 cm below the upper limit of the *argic horizon*;

and

2. show *retic properties* in the *argic horizon*;

   and

3. have continuous tongues consisting of coarser-textured material, as defined in the *retic properties*, that start at the upper limit of the *argic horizon*, with all of the following
   a. have a vertical extension of ≥ 30 cm; ***and***
   b. have a horizontal extension of ≥ 1 cm; ***and***
   c. occupy ≥ 10 and < 90% of the exposed area.

Relationships with some other diagnostics

Albeluvic glossae are a special case of *retic properties*. In *retic properties*, the coarser-textured parts may be thinner and are not necessarily vertically continuous. *Retic properties* may also be present in *natric horizons* whereas albeluvic glossae are defined only in *argic horizons*. The *argic horizon* into which the albeluvic glossae penetrate may also fulfil the diagnostic criteria of a *fragic horizon*. In undisturbed soils, the *argic horizon* with the albeluvic glossae is typically overlain by an *albic* or *cambic horizon*. However, the overlying horizons may be lost due to erosion or ploughing.

3.2.3 Andic properties

General description

Andic properties (from Japanese *an*, dark, and *do*, soil) result from moderate weathering of mainly pyroclastic deposits. The presence of short-range-order minerals and/or organo-metallic complexes is characteristic for andic properties. These minerals and complexes are commonly part of the weathering sequence in pyroclastic deposits (*tephric material* → *vitric properties* → andic properties). However, andic properties with organo-metallic complexes may also form in non-pyroclastic silicate-rich materials in cool-temperate and humid climates.

Diagnostic criteria

Andic properties require:

1. a bulk density of ≤ 0.9 kg dm^{-3}; ***and***
2. an Al_{ox} + ½Fe_{ox} value of ≥ 2%; ***and***
3. a phosphate retention of ≥ 85%.

Field identification

Andic properties may be identified using the sodium fluoride field test of Fieldes and Perrott (1966). A pH in NaF of ≥ 9.5 indicates allophane and/or organo-aluminium complexes in carbonate-free soils. The test is indicative for most layers with andic properties, except for those very rich in organic matter. However, the same reaction occurs in *spodic horizons* and in certain acid clays that are rich in Al-interlayered clay minerals.

Andic layers may exhibit thixotropy, i.e. the soil material changes, under pressure or by rubbing, from a plastic solid into a liquefied stage and back into the solid condition.

Additional information

Andic properties may be found at the soil surface or in the subsurface, commonly occurring as layers. Many surface layers with andic properties contain a high amount of organic matter (≥ 5%), are commonly very dark coloured (Munsell colour value and chroma of ≤ 3, moist), have a fluffy macrostructure, and in some places show thixotropy. They have a low bulk density and commonly have a silt loam or finer texture. Andic surface layers rich in organic matter may be very thick, having a thickness of ≥ 50 cm in some soils. Andic

subsurface layers are generally somewhat lighter coloured.
In perhumid climates, humus-rich andic layers may contain more than twice the water content of samples that have been dried at 105 °C and rewetted (hydric characteristic).
For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined at 105 °C.
Two major types of andic properties are recognized: one in which allophane, imogolite and similar minerals are predominant (Silandic qualifier); and one in which Al complexed by organic acids prevails (Aluandic qualifier). The silandic property typically gives a strongly acid to neutral soil reaction and is a bit lighter coloured, while the aluandic property gives an extremely acid to acid reaction and a blackish colour. Uncultivated, organic matter-rich surface layers with silandic properties typically have a pH_{water} of ≥ 4.5, while uncultivated surface layers with aluandic properties and rich in organic matter typically have a pH_{water} of < 4.5. Generally, pH_{water} in silandic subsoil layers is ≥ 5.

Relationships with some other diagnostics

Vitric properties are distinguished from andic properties by a lesser degree of weathering. This is evidenced by the presence of volcanic glasses and usually by a lower amount of short-range-order pedogenic minerals and/or organo-metallic complexes, as characterized by a lower amount of Al_{ox} and Fe_{ox}, a higher bulk density, or a lower phosphate retention. The diagnostic criteria of the *vitric* and andic *properties* are adapted after Shoji et al. (1996), Takahashi et al. (2004) and findings of the COST 622 Action.
Spodic horizons, which also contain complexes of oxides and organic substances, can exhibit andic properties as well. Andic properties may also be present in *chernic, mollic* or *umbric horizons*.

3.2.4 Anthric properties

General description

Anthric properties (from Greek *anthropos*, human being) refer to human-made *mollic* or *umbric horizons*. Some of the *mollic horizons* with anthric properties are natural *umbric horizons* transformed into *mollic horizons* by liming and fertilization. Thin, light-coloured or humus-poor mineral topsoil horizons may be transformed into *umbric* or even *mollic horizons* by long-term cultivation (ploughing, liming, fertilization etc.). Another group of artificial *mollic* or *umbric horizons* is created by ploughing organic surface layers into the mineral soil. In all these cases, the soil has very little animal activity, which is especially uncommon for soils with a *mollic horizon*.

Diagnostic criteria

Anthric properties:

1. occur in soils with a *mollic* or *umbric horizon*;
   and
2. show evidence of human disturbance by one or more of the following:
   a. an abrupt lower boundary at ploughing depth and ≥ 10% of the sand grains not coated by organic matter; ***or***
   b. an abrupt lower boundary at ploughing depth and evidence of mixing of humus-richer and humus-poorer soil materials by ploughing; ***or***
   c. lumps of applied lime; ***or***
   d. ≥ 430 mg kg^{-1} P in the Mehlich-3 extract in the upper 20 cm;
   and
3. show < 5% (by exposed area) of animal pores, coprolites or other traces of soil animal activity in one or both of the following depths:
   a. in the lowermost 5 cm of the *mollic* or *umbric horizon*; ***or***

   b. in a depth range of 5 cm below the plough layer, if present.

Field identification

Signs of mixing or cultivation, evidence of liming (e.g. remnants of applied lime chunks), the dark colour and the almost complete absence of traces of soil animal activity are the main criteria for recognition. Incorporated humus-richer material may be established with the naked eye, using a 10x hand lens or using thin sections, depending on the degree of fragmentation/dispersion of the humus-richer material. The incorporated humus-richer material is typically weakly bound to the humus-poorer material, which is manifested by uncoated sand grains in a darker matrix throughout the mixed layer.

Additional information

430 mg kg^{-1} P in the Mehlich-3 extract roughly correspond to 654 mg kg^{-1} P or 1500 mg kg^{-1} P_2O_5 in 1% citric acid (Kabała et al., 2018), which was the requirement in former editions of WRB. The original idea of the anthric properties is derived from Krogh & Greve (1999).

Relationships with some other diagnostics

Anthric properties are an additional characteristic of some *mollic* or *umbric horizons*. *Chernic horizons* normally show a higher animal activity and do not have anthric properties.

3.2.5 Continuous rock

Diagnostic criteria

Continuous rock (from Latin *continuare*, to continue) is consolidated material, exclusive of cemented pedogenic horizons such as *limonic*, *petrocalcic*, *petroduric*, *petrogypsic*, *petroplinthic* and *spodic horizons*. Continuous rock is sufficiently consolidated to remain intact when an air-dried specimen, 25–30 mm on one side, is submerged in water for 1 hour. The material is considered continuous only if cracks occupy < 10% (by volume) of the continuous rock, with no significant displacement of the rock having taken place.

3.2.6 Gleyic properties

General description

Gleyic properties (from Russian folk name *gley*, wet bluish clay) develop in layers that are saturated with groundwater (or were saturated in the past, if now drained) for a period that allows *reducing conditions* to occur (this may range from a few days in the tropics to a few weeks in other areas) and in the capillary fringe above them. There may be gleyic properties without the presence of groundwater in a clay-rich layer over a layer rich in sand or coarse fragments. In some soils with gleyic properties, the *reducing conditions* are caused by upward moving gases such as methane or carbon dioxide. If there are no more *reducing conditions*, the gleyic properties are relict.

Diagnostic criteria

Gleyic properties refer to *mineral material*, show redoximorphic features and comprise one of the following:

1. a layer with ≥ 95% (by exposed area) reductimorphic features that have the following Munsell colours, moist:
   a. a hue of N, 10Y, GY, G, BG, B or PB; ***or***
   b. a hue of 2.5Y or 5Y and a chroma of ≤ 2;

   or
2. a layer with > 5% (by exposed area, related to the fine earth plus oximorphic features of any size and any cementation class) oximorphic features that:

   a. are predominantly on biopore walls and, if soil aggregates are present, predominantly on or adjacent to aggregate surfaces; ***and***
   b. have a Munsell colour hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher, moist, than the surrounding material or than the matrix of the directly underlying layer;

   or
3. a combination of two layers: a layer fulfilling diagnostic criterion 2 and a directly underlying layer fulfilling diagnostic criterion 1.

Field identification
Redoximorphic features are described in Annex 1 (Chapter 8.4.20).

Additional information
Gleyic properties result from a redox gradient between groundwater and the capillary fringe causing an uneven distribution of iron or manganese (hydr-)oxides. In the lower part of the soil and/or inside the soil aggregates, the oxides are either transformed into soluble Fe/Mn(II) compounds or they are translocated; both processes lead to the absence of colours that have a Munsell hue redder than 2.5Y. Translocated Fe and Mn compounds can be concentrated in the oxidized form (Fe[III], Mn[IV]) on soil aggregate surfaces or on biopore walls (rusty root channels), and towards the surface even in the matrix. Mn concentrations can be recognized by strong effervescence using a 10% H_2O_2 solution.
Reductimorphic features reflect permanently wet conditions. In loamy and clayey material, blue-green colours predominate owing to Fe(II, III) hydroxy salts (green rust). If the material is rich in sulfur (S), blackish colours prevail owing to colloidal iron sulfides such as greigite or mackinawite (easily recognized by smell, after applying 1 *M* HCl). In calcareous material, whitish colours are dominant owing to calcite and/or siderite. Sands are usually light grey to white in colour and also often impoverished in Fe and Mn. Bluish-green and black colours are unstable and often oxidize to a reddish brown colour within a few hours of exposure to air. The upper part of a reductimorphic layer may show up to 5% rusty colours, mainly around channels of burrowing animals or plant roots.
Oximorphic features reflect oxidizing conditions, as in the capillary fringe and in the surface horizons of soils with fluctuating groundwater levels. Specific colours indicate ferrihydrite (reddish brown), goethite (bright yellowish brown), lepidocrocite (orange), schwertmannite (dark orange) and jarosite (pale yellow). In loamy and clayey soils, the iron oxides/hydroxides are concentrated on soil aggregate surfaces and the walls of larger pores (e.g. old root channels).
In most cases, a layer fulfilling diagnostic criterion 2 overlies a layer fulfilling criterion 1. Some soils, including underwater soils (freshwater or seawater) and tidal soils have only a layer that fulfils diagnostic criterion 1 and no layer fulfilling criterion 2.

Relationships with some other diagnostics
Gleyic properties differ from *stagnic properties*. Gleyic properties are caused by an upward moving agent (mostly groundwater) that causes *reducing conditions* and that leads to an underlying strongly reduced layer and an overlying layer with oximorphic features on or adjacent to soil aggregate surfaces. (In some soils only one of these layers is present.) *Stagnic properties* are caused by stagnation of an intruding agent (mostly rainwater) that causes *reducing conditions* and that leads to an overlying Fe-poor layer and an underlying layer with oximorphic features inside the soil aggregates. (In some soils, only one of these layers is present.)

3.2.7 Lithic discontinuity

General description
Lithic discontinuities (from Greek *lithos*, stone, and Latin *continuare*, to continue) represent significant

differences in parent material within a soil. A lithic discontinuity can also denote different times of deposition. The different strata may have the same or a different mineralogy.

Diagnostic criteria

When comparing two directly superimposed layers consisting of *mineral material*, a lithic discontinuity requires one or more of the following:

1. an abrupt difference in particle-size distribution that is not solely associated with a change in clay content resulting from soil formation;
   or
2. both of the following:
   a. one or more of the following:
      i. ≥ 10% coarse sand and ≥ 10% medium sand, ***and*** a difference of ≥ 25% in the ratio coarse sand to medium sand, ***and*** a difference of ≥ 5% (absolute) in the content of coarse sand and/or medium sand; ***or***
      ii. ≥ 10% coarse sand and ≥ 10% fine sand, ***and*** a difference of ≥ 25% in the ratio coarse sand to fine sand, ***and*** a difference of ≥ 5% (absolute) in the content of coarse sand and/or fine sand; ***or***
      iii. ≥ 10% medium sand and ≥ 10% fine sand, ***and*** a difference of ≥ 25% in the ratio medium sand to fine sand, ***and*** a difference of ≥ 5% (absolute) in the content of medium sand and/or fine sand; ***or***
      iv. ≥ 10% sand and ≥ 10% silt, ***and*** a difference of ≥ 25% in the ratio sand to silt, ***and*** a difference of ≥ 5% (absolute) in the content of sand and/or silt;
   and
   b. the differences do not result from original variation within the parent material in the form of patches of different particle-size fractions within a layer;
   or
3. the layers have coarse fragments with different lithology;
   or
4. a layer containing coarse fragments without weathering rinds overlying a layer containing coarse fragments with weathering rinds;
   or
5. a layer with angular coarse fragments overlying or underlying a layer with rounded coarse fragments;
   or
6. an overlying layer that has ≥ 10% (absolute, by volume, related to the whole soil) more coarse fragments than the underlying layer, unless the difference is created by animal activity;
   or
7. a lower amount of coarse fragments in the overlying layer that cannot be explained by advanced weathering in the overlying layer;
   or
8. abrupt differences in colour not resulting from soil formation;
   or
9. marked differences in size and shape of resistant minerals (as shown by micromorphological or mineralogical methods);
   or
10. differences in the TiO_2/ZrO_2 ratios of the sand fraction by a factor of ≥ 2;
    or
11. differences in CEC (by 1 *M* NH_4OAc, pH 7) per kg clay by a factor of ≥ 2.

Additional information

In some cases, a lithic discontinuity may be suggested by one of the following: a horizontal line of coarse fragments (stone line) overlying and underlying layers with lesser amounts of coarse fragments, or a decreasing percentage of coarse fragments with increasing depth. On the other hand, the sorting action of small fauna such as termites can produce similar effects in what would initially have been lithicly uniform parent material.

Diagnostic criterion 2 is illustrated by the following example:

Layer 1: 20% coarse sand, 10% medium sand → ratio coarse sand to medium sand: 2.
Layer 2: 15% coarse sand, 10% medium sand → ratio coarse sand to medium sand: 1.5.
Difference in ratios: 25%
Difference in contents of coarse sand (absolute): 5%
Difference in contents of medium sand (absolute): 0
Result: between the two layers, there is a lithic discontinuity.

Generally, the mathematical formula for calculating differences in ratios is:

$ABS(ratio_i - ratio_{i+1})/MAX(ratio_i; ratio_{i+1})*100$

3.2.8 Protocalcic properties

General description

Protocalcic properties (from Greek *proton*, first, and Latin *calx*, lime) refer to carbonates that are derived from the soil solution and precipitated in the soil. They do not belong to the soil parent material or to other sources such as dust. They occur across the soil structure or fabric. These carbonates are called secondary carbonates. For protocalcic properties, they must be permanent and be present in significant quantities.

Diagnostic criteria

Protocalcic properties refer to accumulations of secondary carbonates, visible when moist, that

1. occupy ≥ 5% of the exposed area (related to the fine earth plus accumulations of secondary carbonates of any size and any cementation class) with masses, nodules, concretions or filaments; ***or***
2. cover ≥ 10% of the surfaces of soil aggregates or biopore walls; ***or***
3. cover ≥ 10% of the underside surfaces of coarse fragments or of remnants of a cemented horizon.

Field identification

The identification of secondary carbonates is described in Annex 1 (Chapter 8.4.25).

Additional information

Accumulations of secondary carbonates qualify as protocalcic properties only if they are permanent and do not come and go with changing moisture conditions. This should be checked by spraying some water on them.

Relationships with some other diagnostics

Accumulations of secondary carbonates with higher contents of calcium carbonate equivalent may qualify for a *calcic horizon*, or if continuously cemented with a cementation class of at least moderately cemented, for a *petrocalcic horizon*. *Calcaric material* refers to the presence of carbonates in the entire fine earth, which usually includes primary carbonates.

3.2.9 Protogypsic properties

General description

Protogypsic properties (from Greek *proton*, first, and *gypsos*, gypsum) refer to gypsum that is derived from the soil solution and precipitated in the soil. It does not belong to the soil parent material or to other sources such as dust. This gypsum is called secondary gypsum.

Diagnostic criteria

Protogypsic properties refer to visible accumulations of secondary gypsum that occupy ≥ 1% of the exposed area (related to the fine earth plus accumulations of secondary gypsum of any size and any cementation class).

Field identification

The identification of secondary gypsum is described in Annex 1 (Chapter 8.4.26).

Relationships with some other diagnostics

Accumulations of secondary gypsum with higher gypsum contents may qualify for a *gypsic horizon*, or if continuously cemented, for a *petrogypsic horizon*. *Gypsiric material* includes primary gypsum.

3.2.10 Reducing conditions

Diagnostic criteria

Reducing conditions (from Latin *reducere*, to draw back) show one or more of the following:

1. a negative logarithm of the hydrogen partial pressure (rH, calculated as $Eh \cdot 29^{-1} + 2 \cdot pH$) of < 20; ***or***
2. the presence of free Fe^{2+}, as shown on a freshly broken and smoothed surface of a field-wet soil by the appearance of a strong red colour after wetting it with 0.2% α,α-dipyridyl dissolved in 1 *N* ammonium acetate (NH_4OAc), pH 7; ***or***
3. the presence of iron sulfide; ***or***
4. the presence of methane.

Caution: α,α-dipyridyl solution is toxic if swallowed and harmful if absorbed through skin or inhaled. It has to be used with care. In layers with a neutral or alkaline soil reaction it may not give the strong red colour.

3.2.11 Retic properties

General description

Retic properties (from Latin *rete*, net) describe the interfingering of coarser-textured *claric material* into a finer-textured *argic* or *natric horizon*. The interfingering coarser-textured *claric material* is characterized by a partial removal of clay minerals and iron oxides. There may be also coarser-textured *claric material* falling from the overlying horizon into cracks in the *argic* or *natric horizon*. The coarser-textured *claric material* is found as vertical, horizontal and inclined interfingerings between soil aggregates.

Diagnostic criteria

Retic properties refer to a combination of finer-textured parts and coarser-textured parts, both consisting of *mineral material*, within the same layer, with all of the following:

1. the finer-textured parts belong to an *argic* or *natric horizon*;
   and
2. the coarser-textured parts consist of *claric material*;
   and
3. the finer-textured parts have, compared with the coarser-textured parts, the following Munsell colour, moist:
   a. a hue ≥ 2.5 units redder: ***or***
   b. a value ≥ 1 unit lower; ***or***

   c. a chroma ≥ 1 unit higher;
   and
4. the clay content of the finer-textured parts is higher compared with the coarser-textured parts, as specified for the *argic* or *natric horizon*, criterion 2.a;
   and
5. the coarser-textured parts are ≥ 0.5 cm wide;
   and
6. the coarser-textured parts start at the upper limit of the *argic* or *natric horizon*;
   and
7. the coarser-textured parts occupy areas ≥ 10 and < 90% in both vertical and horizontal sections, within
   a. the upper 30 cm of the *argic* or *natric horizon*; ***or***
   b. the entire *argic* or *natric horizon*,
   whichever is thinner;
   and
8. do not occur within a plough layer.

Relationships with some other diagnostics

Retic properties include the special case of *albeluvic glossae*. The *argic* or *natric horizons* that exhibit retic properties may also satisfy the requirements of a *fragic horizon*. A layer with retic properties may also show *stagnic properties* with or without *reducing conditions*. In undisturbed soils, the *argic* or *natric horizon* with the retic properties is typically overlain by an *albic* or *cambic horizon*. However, the overlying horizons may be lost due to erosion or ploughing.

3.2.12 Shrink-swell cracks

General description

Shrink-swell cracks open and close due to shrinking and swelling of clay minerals with changing water content of the soil. They may be evident only when the soil is dry. They control the infiltration and percolation of water, even if they are filled with material from the surface.

Diagnostic criteria

Shrink-swell cracks occur in *mineral material* and:
1. open and close with changing water content of the soil; ***and***
2. are ≥ 0.5 cm wide, when the soil is dry, with or without infillings of material from the surface.

Relationships with some other diagnostics

Shrink-swell cracks are referred to in the diagnostic criteria of the *protovertic horizon*, the *vertic horizon* and in the Key to the Reference Soil Groups (where reference is made to their depth requirements).

3.2.13 Sideralic properties

General description

Sideralic properties (from Greek *sideros*, iron, and Latin *alumen*, alum) refer to *mineral material* that has a relatively low CEC.

Diagnostic criteria

Sideralic properties occur in *mineral material* and require:
1. one or both of the following:

   a. ≥ 8% clay ***and*** a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay; ***or***
   b. a CEC (by 1 *M* NH_4OAc, pH 7) of < 2 $cmol_c$ kg^{-1} soil;

   and
2. evidence of soil formation as defined in criterion 3 of the *cambic horizon*.

Relationships with some other diagnostics

Sideralic properties are also present in *ferralic horizons*.

3.2.14 Stagnic properties

General description

Stagnic properties (from Latin *stagnare*, to flood) form in layers that are, at least temporarily, saturated with stagnant water (or were saturated in the past, if now drained) for a period long enough that allows *reducing conditions* to occur (this may range from a few days in the tropics to a few weeks in other areas). In some soils with stagnic properties, the *reducing conditions* are caused by the intrusion of other liquids such as gasoline. If there are no more *reducing conditions*, the stagnic properties are relict.

Diagnostic criteria

Stagnic properties refer to *mineral material*, show redoximorphic features and comprise one or more of the following:

1. a layer that comprises reductimorphic features and soil material with the matrix colour and that shows both of the following:
   a. the reductimorphic features are predominantly around biopores and, if soil aggregates are present, predominantly at the outer parts of the aggregates; ***and***
   b. the reductimorphic features have, compared against the matrix colour, the following Munsell colours, moist: a value ≥ 1 unit higher and a chroma ≥ 1 unit lower;

   or
2. a layer that comprises oximorphic features and soil material with the matrix colour and that shows both of the following:
   a. the oximorphic features are, if soil aggregates are present, predominantly inside the aggregates; ***and***
   b. the oximorphic features are black, surrounded by lighter-coloured material, or have, compared against the matrix colour, the following Munsell colours, moist: a hue ≥ 2.5 units redder and a chroma ≥ 1 unit higher;

   or
3. a layer that comprises reductimorphic features and oximorphic features (with or without soil material with a matrix colour) and that shows all of the following:
   a. the reductimorphic features are predominantly around biopores and, if soil aggregates are present, predominantly at the outer parts of the aggregates;
      and
   b. the oximorphic features are, if soil aggregates are present, predominantly inside the aggregates;
      and
   c. the oximorphic features are black, surrounded by lighter-coloured material, or have, compared against the reductimorphic features, one or more of the following Munsell colours, all moist:
      i. a hue ≥ 5 units redder; ***or***
      ii. a chroma ≥ 4 units higher; ***or***
      iii. a hue ≥ 2.5 units redder and a chroma ≥ 2 units higher; ***or***
      iv. a hue ≥ 2.5 units redder, a value ≥ 1 unit lower and a chroma ≥ 1 unit higher;

   or

4. a layer with the colours of *claric material* in ≥ 95% of its exposed area, which is considered as reductimorphic feature, above an *abrupt textural difference* or above a layer with a bulk density of ≥ 1.5 kg dm^{-1};
   or
5. a combination of two layers: a layer with *claric material* in ≥ 95% of its exposed area, which is considered as reductimorphic feature, and a directly underlying layer fulfilling the diagnostic criteria 1, 2 or 3.

Field identification

Redoximorphic features are described in Annex 1 (Chapter 8.4.20).

Additional information

Stagnic properties result from a reduction of iron and/or manganese (hydr-)oxides around the larger pores. Mobilized Mn and Fe may be washed out laterally resulting in *claric material* (especially in the upper part of the profile that is coarser textured in many soils) or may migrate into the interiors of the soil aggregates where they are reoxidized (especially in the lower part of the profile).
If the stagnic properties are weakly expressed, the reductimorphic and oximorphic features cover only some parts of the exposed area, and the other parts show the original matrix colour that prevailed in the soil before the redox processes started. If the stagnic properties are strongly expressed, the entire exposed area of the fine earth shows either reductimorphic or oximorphic features.

Relationships with some other diagnostics

Stagnic properties differ from g*leyic properties*. Stagnic properties are caused by stagnation of an intruding agent (mostly rainwater) that causes *reducing conditions* and that leads to an overlying Fe-poor layer and an underlying layer with oximorphic features inside the soil aggregates. (In some soils, only one of these layers is present.) *Gleyic properties* are caused by an upward moving agent (mostly groundwater) that causes *reducing conditions* and that leads to an underlying strongly reduced layer and an overlying layer with oximorphic features on or adjacent to the soil aggregate surfaces. (In some soils, only one of these layers is present.)

3.2.15 Takyric properties

General description

Takyric properties (from Turkic languages *takyr*, barren land) are related to a fine-textured surface crust with a platy or massive structure. They occur under arid conditions in periodically flooded soils.

Diagnostic criteria

Takyric properties refer to a surface crust consisting of *mineral material* that has all of the following:

1. a texture class of clay loam, silty clay loam, silty clay or clay;
   and
2. a platy or massive structure;
   and
3. polygonal cracks, ≥ 2 cm deep and with an average horizontal spacing of ≤ 20 cm, when the soil is dry;
   and
4. a rupture-resistance class of at least hard when dry and a plasticity of at least moderately plastic when moist;
   and
5. an electrical conductivity (EC_e) of the saturation extract of

a. < 4 dS m^{-1}; ***or***
b. at least 1 dS m^{-1} less than that of the layer directly below the surface crust.

Field identification
Takyric properties occur in depressions in arid regions, where surface water, rich in clay and silt but relatively low in soluble salts, accumulates and leaches salts out of the upper soil horizons. This causes clay dispersion and the formation of a thick, compact, fine-textured crust with prominent polygonal cracks when dry. The crust often contains ≥ 80% clay and silt. It is thick enough that it does not curl entirely upon drying.

Relationships with some other diagnostics
Takyric properties occur in association with many diagnostic horizons, the most important ones being the *natric*, *salic*, *gypsic*, *calcic* and *cambic horizons*. The low EC and low soluble-salt content of takyric properties set them apart from the *salic horizon*.

3.2.16 Vitric properties

General description
Vitric properties (from Latin *vitrum*, glass) apply to layers that contain glass from volcanic or industrial origin and that contain a limited amount of short-range-order minerals or organo-metallic complexes.

Diagnostic criteria
Vitric properties require:
1. in the fraction between > 0.02 and ≤ 2 mm, ≥ 5% (by grain count) volcanic glass, glassy aggregates, other glass-coated primary minerals or glasses resulting from industrial processes; ***and***
2. an Al_{ox} + ½Fe_{ox} value of ≥ 0.4%; ***and***
3. a phosphate retention of ≥ 25%.

Field identification
Vitric properties can occur in a surface layer. However, they can also occur under some tens of centimetres of recent pyroclastic deposits. Layers with vitric properties can have an appreciable amount of organic matter. The sand and coarse silt fractions of layers with vitric properties have a significant amount of unaltered or partially altered volcanic glass, glassy aggregates, other glass-coated primary minerals or glassses resulting from industrial processes (coarser fractions may be checked by using a 10x hand lens; finer fractions may be checked by using a microscope).

Relationships with some other diagnostics
Vitric properties are, on the one hand, closely linked with *andic properties*, into which they may eventually develop. For some time during this development, a layer may show both the amount of volcanic glasses required for the vitric properties and the characteristics of *andic properties*. On the other hand, layers with vitric properties develop from *tephric material*. The diagnostic criteria of the vitric and *andic properties* are adapted after Shoji et al. (1996), Takahashi et al. (2004) and findings of the COST 622 Action.
Chernic, *mollic* and *umbric horizons* may exhibit vitric properties as well.

3.2.17 Yermic properties

General description
Yermic properties (from Spanish *yermo*, desert) are found on the mineral soil surface in deserts. They comprise features like desert pavement, desert varnish, ventifacts (windkanters), a platy structure and

vesicular pores.

Diagnostic criteria

Yermic properties occur in *mineral material* and have one or both of the following:

1. coarse surface fragments covering ≥ 20% of the soil surface (desert pavement), underlain by a soil layer with an abundance of coarse fragments half or less the abundance of coarse surface fragments, and one or more of the following:
   a. ≥ 10% of the coarse surface fragments, > 2 cm (greatest dimension), are varnished; ***or***
   b. ≥ 10% of the coarse sruface fragments, > 2 cm (greatest dimension), are wind-shaped (ventifacts, windkanters); ***or***
   c. a surface layer, ≥ 1 cm thick, with a platy structure; ***or***
   d. a surface layer, ≥ 1 cm thick, with many vesicular pores;

   or
2. a surface layer, not compacted by human activity, ≥ 1 cm thick, with a platy structure and many vesicular pores.

Field identification

The features of the yermic properties are described in Annex 1:
desert pavement (Chapter 8.3.4)
desert varnish and ventifacts (Chapter 8.3.5)
platy structure (Chapter 8.4.10)
vesicular pores (Chapter 8.4.12) - to be diagnostic, the vesicular pores must be present in the abundance class 'many'.
If the texture is fine enough, the soil may show a polygonal network of desiccation cracks (Chapter 8.4.13), often filled with in-blown material, that extend into greater depths. In cold deserts, larger coarse fragments at the soil surface are often shattered by frost.

Relationships with some other diagnostics

Yermic properties often occur in association with other diagnostics, characteristic for desert environments (*salic*, *duric, gypsic*, *calcic* and *cambic horizons*). In very cold deserts (e.g. Antarctica), they may occur associated with *cryic horizons*. Under these conditions, coarse cryoclastic material dominates, and there is little dust to be deflated and deposited by wind. Here, a dense pavement with varnish, ventifacts, aeolian sand layers and accumulations of soluble minerals may occur directly on loose deposits, without vesicular pores.

3.3 Diagnostic materials

Diagnostic materials are materials that significantly influence soil-forming processes. Their characteristics may be inherited from the parent material or may be the result of soil-forming processes. Diagnostic materials do not describe parent material; they describe soil material, and the characteristics refer (as for all diagnostics) to the fine earth, unless stated otherwise. Their features can be observed or measured in the field or the laboratory and require a minimum or maximum expression to qualify as diagnostic. A minimum thickness is not part of the criteria.

3.3.1 Aeolic material

General description

Aeolic material (from Greek *aiolos*, wind) describes material deposited by wind, typical in arid and semi-arid environments.

Diagnostic criteria

Aeolic material requires:

1. evidence of wind deposition within 20 cm from the mineral soil surface by one or both of the following:
   a. 10% of the particles of medium and coarse sand are rounded or subangular and have a matt surface, in some layer or in in-blown material filling cracks; ***or***
   b. aeroturbation (e.g. cross-bedding) in some layer;

   and
2. < 1% *soil organic carbon* from the mineral soil surface to a depth of 10 cm.

3.3.2 Artefacts

General description

Artefacts describe human-made, human-altered and human-excavated material. They may by physically altered (e.g. broken to pieces) but are chemically and mineralogically not or only poorly altered and still largely recognizable.

Diagnostic criteria

Artefacts (from Latin *ars*, art, and *factus*, made) are liquid or solid substances of any size that:

1. are one or both of the following:
   a. created or substantially modified by humans as part of industrial or artisanal manufacturing processes; ***or***
   b. brought to the soil surface by human activity from a depth, where they were not influenced by surface processes, and deposited in an environment, where they do not commonly occur, with properties substantially different from the environment where they are placed;

   and
2. have substantially the same chemical and mineralogical properties as when first manufactured, modified or excavated.

Additional information

Examples of artefacts are bricks, pottery, glass, crushed or dressed stone, wooden boards, industrial waste, plastic, garbage, processed oil products, bitumen, mine spoil and crude oil.

Relationships with some other diagnostics

Technic hard material and geomembranes, intact, fractured or composed, also fulfil the diagnostic criteria of artefacts.

3.3.3 Calcaric material

General description

Calcaric material (from Latin *calcarius*, containing lime) refers to material that contains ≥ 2% calcium carbonate equivalent. The carbonates are at least partially inherited from the parent material (primary carbonates).

Diagnostic criteria

Calcaric material shows visible effervescence with 1 *M* HCl throughout the fine earth.

Relationships with some other diagnostics

Calcaric material may also meet the diagnostic criteria of *protocalcic properties*, which show discernible accumulations of secondary carbonates. *Calcic* and *petrocalcic horizons* have higher contents of carbonates and also show secondary carbonates. *Petrocalcic horizons* are continuously cemented.

3.3.4 Claric material

General description

Claric material (from Latin *clarus*, bright) is light-coloured fine earth.

Diagnostic criteria

Claric material is *mineral material* and:

1. has in ≥ 90% of its exposed area a Munsell colour, dry, with one or both of the following:
   a. a value of ≥ 7 and a chroma of ≤ 3; ***or***
   b. a value of ≥ 5 and a chroma of ≤ 2;

   and
2. has in ≥ 90% of its exposed area a Munsell colour, moist, with one or more of the following:
   a. a value of ≥ 6 and a chroma of ≤ 4;
      or
   b. a value of ≥ 5 and a chroma of ≤ 3;
      or
   c. a value of ≥ 4 and a chroma of ≤ 2;
      or
   d. all of the following:
      i. a hue of 5YR or redder; ***and***
      ii. a value of ≥ 4 and a chroma of ≤ 3; ***and***
      iii. ≥ 25% of the sand and coarse silt grains are uncoated.

Field identification

Identification in the field depends on soil colours. In addition, a 10x hand lens may be used to ascertain that sand and coarse silt grains are free of coatings (criterion 2.d). Claric material may exhibit a considerable shift in chroma when wetted.

Additional information

The presence of coatings around sand and coarse silt grains can be determined using an optical microscope for analysing thin sections. Uncoated grains usually show a very thin rim at their surface. Coatings may be of an organic nature, consist of iron oxides, or both, and are dark-coloured under translucent light. Iron coatings become reddish in colour under reflected light, while organic coatings remain brownish-black.

Relationships with some other diagnostics

The claric material is used as a diagnostic criterion in the definition of the *spodic horizon*, the *retic* and the *stagnic properties*. A layer with claric material that has lost oxides and/or organic matter due to clay migration, podzolization or due to redox processes caused by stagnant water, forms an *albic horizon*.

3.3.5 Dolomitic material

Diagnostic criteria

Dolomitic material (named after the French geoscientist *Déodat de Dolomieu*) shows visible effervescence with heated 1 *M* HCl throughout the fine earth. It applies to material that contains ≥ 2% of a mineral that has a ratio $CaCO_3/MgCO_3 < 1.5$. With non-heated HCl, it gives only a retarded and poorly visible effervescence.

3.3.6 Fluvic material

General description

Fluvic material (from Latin *fluvius*, river) refers to fluviatile, marine and lacustrine sediments that receive fresh material or have received it in the past and still show stratification. Fluvic material shows only little soil formation after deposition.

Diagnostic criteria

Fluvic material is *mineral material* and:

1. is of fluviatile, marine or lacustrine origin;
   and
2. has strata that are one or both of the following:
   a. obvious (including stratification tilted by cryogenic alteration) in ≥ 25% (by volume, related to the whole soil) over a specified depth;
      or
   b. evidenced by two or more layers with all of the following:
      i. ≥ 0.2% *soil organic carbon*; ***and***
      ii. a content of *soil organic carbon* ≥ 25% (relative) and ≥ 0.2% (absolute) higher than in the directly overlying layer; ***and***
      iii. does not form part of a *natric* or *spodic horizon*;
   and
3. one or both of the following:
   a. has a single grain, a massive, a platy or a weak subangular blocky structure; ***or***
   b. has a granular or a subangular blocky structure in a layer that meets diagnostic criteria 2.b.

Field identification

Stratification may be reflected in different ways:

- variation in texture and/or content or nature of coarse fragments
- different colours related to the source materials

- alternating lighter- and darker-coloured soil layers, indicating an irregular decrease in soil organic carbon content with depth.

Relationships with some other diagnostics

Fluvic material is always associated with water bodies (e.g. rivers, lakes, the sea) and can therefore be distinguished from *solimovic material*. It may also fulfil the criteria of *limnic material*.

3.3.7 Gypsiric material

Diagnostic criteria

Gypsiric material (from Greek *gypsos*, gypsum) is *mineral material* that contains ≥ 5% gypsum that is not secondary gypsum.

Relationships with some other diagnostics

Gypsiric material may also meet the diagnostic criteria of *protogypsic properties*, which show discernible accumulations of secondary gypsum. *Gypsic* and *petrogypsic horizons* also show secondary gypsum. *Petrogypsic horizons* have high amounts of gypsum and are continuously cemented.

3.3.8 Hypersulfidic material

General description

Hypersulfidic material (from Greek *hyper*, over, and Latin *sulpur*, sulfur) contains inorganic sulfidic S and is capable of severe acidification as a result of the oxidation of inorganic sulfidic compounds contained within it. Hypersulfidic material is also known as 'potential acid sulfate soil'.

Diagnostic criteria

Hypersulfidic material:

1. has ≥ 0.01% inorganic sulfidic S;
   and
2. has a pH (1:1 by mass in water, or in a minimum of water to permit measurement) of ≥ 4;
   and
3. when a layer, 2–10 mm thick, is incubated aerobically at field capacity for 8 weeks, the pH drops to < 4 and one or more of the following:
   a. within these 8 weeks, the total pH decline is ≥ 0.5 pH units; ***or***
   b. latest after these 8 weeks, the decrease in pH is only ≤ 0.1 pH units over a further period of 14 days; ***or***
   c. latest after these 8 weeks, the pH begins to increase again.

Field identification

Hypersulfidic material is seasonally or permanently waterlogged or forms under largely anaerobic conditions. It has a Munsell colour hue of N, 5Y, 5GY, 5BG, or 5G, a value of ≤ 4, and a chroma of 1, all moist. If the soil is disturbed, an odour of hydrogen sulfide (rotten eggs) may be noticed. This is accentuated by application of 1 *M* HCl.

For a quick screening test that is not definitive, a 10 g sample treated with 50 ml of 30% H_2O_2 will show a fall in pH to ≤ 2.5. Final assessment depends on incubation testing.

Caution: H_2O_2 is a strong oxidant, and sulfides and organic matter will froth violently in a test tube that may become very hot.

Relationships with some other diagnostics

Acidification of hypersulfidic material usually causes the development of a *thionic horizon*. *Hyposulfidic material* has the same criteria for inorganic sulfidic S and for the pH value but is not capable of severe acidification.

3.3.9 Hyposulfidic material

General description

Hyposulfidic material (from Greek *hypo*, under, and Latin *sulpur*, sulfur) contains inorganic sulfidic S and is not capable of severe acidification resulting from the oxidation of inorganic sulfidic compounds contained within it. Although oxidation does not lead to the formation of acid sulfate soils, hyposulfidic material is an important environmental hazard due to processes related to inorganic sulfides. Hyposulfidic material has a self-neutralizing capacity, usually due to the presence of calcium carbonate.

Diagnostic criteria

Hyposulfidic material:

1. has ≥ 0.01% inorganic sulfidic S ; ***and***
2. has a pH (1:1 by mass in water, or in a minimum of water to permit measurement) of ≥ 4; ***and***
3. does not consist of *hypersulfidic material*.

Field identification

Hyposulfidic material forms in similar environments to *hypersulfidic material* and morphologically may be indistinguishable from it. However, it is less likely to be coarse in texture. The hydrogen peroxide screening test (see *hypersulfidic material*) may also be indicative, but final assessment depends on incubation testing. Field tests for fine earth carbonate may be used to indicate whether the soil has some self-neutralizing capacity.

Relationships with some other diagnostics

Acidification of hyposulfidic material usually does not cause the development of a *thionic horizon*. *Hypersulfidic material* has the same criteria for inorganic sulfidic S and for the pH value but is capable of severe acidification.

3.3.10 Limnic material

Diagnostic criteria

Limnic material (from Greek *limnae*, pool) includes both *organic* and *mineral material* and is one or more of the following:

1. deposited in water by precipitation, possibly in combination with sedimentation; ***or***
2. derived from algae; ***or***
3. derived from aquatic plants and subsequently transported; ***or***
4. derived from aquatic plants and subsequently modified by aquatic animals and/or microorganisms.

Field identification

Limnic material is formed as subaquatic deposits and usually stratified. (After drainage it may occur at the soil surface.) Four types of limnic material can be distinguished:

1. *Coprogenous earth* or *sedimentary peat*: organic, identifiable through many faecal pellets and peat residues, Munsell colour value of ≤ 4, moist, slightly viscous water suspension, a non-plastic or slightly

plastic plasticity type, shrinking upon drying, difficult to rewet after drying, and cracking along horizontal planes.

2. *Diatomaceous earth*: mainly diatoms (siliceous), identifiable by irreversible changing of the matrix colour (Munsell colour value of 3 to 5 in field moist or wet condition) upon drying as a result of the irreversibly shrinkage of the organic coatings on diatoms (use 440x microscope).
3. *Marl*: strongly calcareous, identifiable by a Munsell colour value of ≥ 5, moist, and a reaction with 1 *M* HCl. The colour of marl usually does not change irreversibly upon drying.
4. *Gyttja*: small coprogenic aggregates, consisting of organic matter that has been strongly altered by microorganisms, and minerals of predominantly clay to silt size, ≥ 0.5% *soil organic carbon*, a Munsell colour hue of 5Y, GY or G, moist, strong shrinkage after drainage and an rH value of ≥ 13.

3.3.11 Mineral material

General description

In mineral material (from Celtic *mine*, mineral), the properties of the fine earth are dominated by mineral components.

Diagnostic criteria

Mineral material has

1. < 20% *soil organic carbon* (related to the fine earth plus the dead plant residues of any length and a diameter ≤ 5 mm); ***and***
2. < 35% (by volume, related to the whole soil) *artefacts* containing ≥ 20% organic carbon.

Relationships with some other diagnostics

Material that has ≥ 20% *soil organic carbon* is *organic material*. Other material that has ≥ 35% (by volume, related to the whole soil) *artefacts* containing ≥ 20% organic carbon is *organotechnic material*.

3.3.12 Mulmic material

General description

Mulmic material (from German *Mulm*, powdery detritus) is *mineral material* developed from *organic material*. If water-saturated *organic material* is drained, a fast decomposition starts. While the amount of mineral components remains constant, the amount of organic matter decreases, and the organic matter content eventually falls below 20%, resulting in *mineral material*.

Diagnostic criteria

Mulmic material is *mineral material* that has developed from water-saturated *organic material* after drainage and that has:

1. ≥ 8% *soil organic carbon*;
   and
2. single or in combination:
   a. a single grain structure; ***or***
   b. a subangular or angular blocky structure with an average aggregate size of ≤ 2 cm;
   and
3. a Munsell colour chroma of ≤ 2, moist.

3.3.13 Organic material

General description

Organic material (from Greek *organon*, tool) has large amounts of organic matter in the fine earth and/or contains many dead thin plant residues. It may show different stages of decomposition. If still connected to living plants (e.g. *Sphagnum* mosses), it may even be completely undecomposed. If derived from fallen organic residues, it is decomposed to at least the extent that it is not loose and/or that recognizable dead plant tissues comprise ≤ 90% of the volume (related to the fine earth plus all dead plant residues). Fallen organic residues with > 90% recognizable dead plant tissues and still loose are called litter layer (see Chapter 2.1, General rules, and Annex 1, Chapters 8.3.1 and 8.3.2) and are not considered for classification in WRB. (Litter layers are temporally and spatially extremely variable in thickness). On the other hand, decomposition may be advanced until no recognizable dead plant tissues remain, and a homogeneous organic soil mass results. Organic material accumulates under both wet and dry conditions. The mineral component of the fine earth has a limited influence on soil properties.

Diagnostic criteria

Organic material

1. has ≥ 20% *soil organic carbon* (related to the fine earth plus the dead plant residues of any length and a diameter ≤ 5 mm);
   and
2. one or more of the following
   a. contains ≤ 90% (by volume, related to the fine earth plus all dead plant residues) recognizable dead plant tissues ***or***
   b. is not loose; ***or***
   c. consists of dead plant material still connected to living plants.

Additional information

20% organic carbon roughly correspond to 40% organic matter. The remaining up to 60% consist of mineral components and/or of organic components that meet the criteria of *artefacts*.

Relationships with some other diagnostics

Soil organic carbon is organic carbon that does not meet the set of diagnostic criteria of *artefacts*. Material that has < 20% *soil organic carbon* is either *organotechnic* or *mineral material. Histic* and *folic horizons* consist of *organic material*.

3.3.14 Organotechnic material

General description

Organotechnic material (from Greek *organon*, tool, and *technae*, art) contains large amounts of organic *artefacts*. It contains relatively small amounts of *soil organic carbon* (organic carbon that does not meet the set of diagnostic criteria of *artefacts*).

Diagnostic criteria

Organotechnic material has

1. ≥ 35% (by volume, related to the whole soil) *artefacts* containing ≥ 20% organic carbon; ***and***
2. < 20% *soil organic carbon* (related to the fine earth plus the dead plant residues of any length and a diameter ≤ 5 mm).

Additional information

Examples for organotechnic material are excavated coal, petroleum lenses, plastic, wooden boards and garbage like kitchen slops or baby nappies.

Relationships with some other diagnostics

Material with ≥ 20% *soil organic carbon* is *organic material*, irrespective of the other components. Material with < 20% *soil organic carbon* and lower amounts of organic *artefacts* is *mineral material*.

3.3.15 Ornithogenic material

General description

Ornithogenic material (from Greek *ornis*, bird, and *genesis*, origin) is material with strong influence of bird excrements. It often has a high content of coarse fragments that have been transported by birds.

Diagnostic criteria

Ornithogenic material has:

1. remnants of birds or bird activity (bones, feathers, and sorted coarse fragments of similar size); ***and***
2. ≥ 750 mg kg^{-1} P in the Mehlich-3 extract.

Additional information

750 mg kg^{-1} P in the Mehlich-3 extract roughly correspond to 1090 mg kg^{-1} P or 2500 mg kg^{-1} P_2O_5 in 1% citric acid (Kabała et al., 2018), which was the requirement in former editions of WRB.

3.3.16 Soil organic carbon

Diagnostic criteria

Soil organic carbon (from Greek *organon*, tool, and Latin *carbo*, coal) is organic carbon that does not meet the set of diagnostic criteria of *artefacts*.

Relationships with some other diagnostics

For organic carbon meeting the criteria of *artefacts*, the *Garbic* or the *Carbonic* qualifier may apply.

3.3.17 Solimovic material

General description

Solimovic material (from Latin *solum*, soil, and *movere*, to move) is a heterogeneous mixture of material that has moved downslope, suspended in water. It is dominated by material that underwent soil formation at its original place, e.g. organic matter accumulation or the formation of Fe oxides. It has been transported as a result of erosional wash or soil creep, and the transport may have been accelerated by land-use practices (e.g. deforestation, ploughing, downhill tillage, structure degradation). Solimovic material has been formed in relatively recent times (mostly Holocene). It normally accumulates in slope positions, in depressions or above a barrier on a low-grade slope. The barrier may be natural or human-made (e.g. hedge walls, terraces, benches). After deposition, there was no advanced soil formation.

Diagnostic criteria

Solimovic material is *mineral material* and:

1. is found on slopes, footslopes, toeslopes, fans, in depressions, above barriers, along gullies or similar relief positions, originating from upslope positions where it was subject to diffuse erosion;

and

2. is not of fluviatile, lacustrine, marine or mass movement origin;

   and

3. one or more of the following:
   a. if burying a mineral soil, it has a lower bulk density than the uppermost layer of the buried soil; ***or***
   b. has ≥ 0.6% *soil organic carbon*; ***or***
   c. has a Munsell colour chroma of ≥ 3, moist; ***or***
   d. contains *artefacts* and/or black carbon of any size; ***or***
   e. has ≥ 100 mg kg^{-1} P in the Mehlich-3 extract;

   and

4. does not form part of a diagnostic horizon other than a *cambic*, *chernic*, *mollic* or *umbric horizon*.

Field identification

The fine earth of solimovic material can be of any particle size. Some small coarse fragments may be included. Solimovic material is generally imperfectly sorted. It may show some gross stratification, but stratification is not a typical feature due to the diffuse or chaotic nature of the deposition process. Solimovic material tends to occupy gently sloping to moderately steep sloping (2-30%) areas. Black carbon or small *artefacts* such as pieces of bricks, ceramics and glass may be present in solimovic material. In many cases, solimovic material has a *lithic discontinuity* at its base.

The upper part of the solimovic material shows characteristics (fine earth texture, colour, pH and *soil organic carbon* content) similar to the surface layer of the source in the neighbourhood. In extreme cases, the profile in the solimovic material mirrors the eroded soil profile of upward slope positions, with topsoil material buried under former subsoil material. Good indication in a landscape is varying colour of the soil surface between convex and concave positions.

Additional information

Accumulations by rapid mass movements such as in landslides, slumps or tree throws do not meet the set of diagnostic criteria of solimovic material.

In agricultural environments, solimovic material has mostly a high base saturation. If not natural, this is the result of liming or fertilization before and/or after having been eroded.

In former editions of WRB, the solimovic material was called colluvic material. However, the traditional use of the word ‘colluvium’ is so different between countries and national traditions and changed so much over time (Miller & Juilleret, 2020) that it is better to avoid this term and use a new one.

Relationships with some other diagnostics

Solimovic material is not associated with perennial water bodies (e.g. rivers, lakes, the sea) and can therefore be distinguished from *fluvic material*. However, in toeslope positions, *fluvic* and solimovic material may be sedimented alternatingly or grade into each other and may be difficult to differentiate.

Solimovic material is not purposefully added as, e.g., the soil material in *terric horizons*.

3.3.18 Technic hard material

General description

Technic hard material (from Greek *technae*, art) describes consolidated material, created or substantially modified by humans.

Diagnostic criteria

Technic hard material:

1. is consolidated material resulting from industrial or artisanal processes; ***and***
2. has properties substantially different from those of natural materials; ***and***
3. is continuous or has free space covering < 5% of its horizontal extension.

Additional information

Examples of technic hard material are asphalt, concrete or a continuous layer of worked stones.

Relationships with some other diagnostics

Technic hard material, intact, fractured or composed, also fulfils the diagnostic criteria of *artefacts*.

3.3.19 Tephric material

General description

Tephric material (from Greek *tephra*, pile ash) has many glasses in the fine earth. These consist of tephra (i.e. unconsolidated, unweathered or only slightly weathered pyroclastic products of volcanic eruptions), of tephric deposits (i.e. tephra that has been reworked and mixed with material from other sources, which includes tephric loess, tephric blown sand and volcanogenic alluvium) or of glasses resulting from industrial processes (e.g. ashes from power stations combusting coal or lignite).

Diagnostic criteria

Tephric material has:

1. in the fraction between > 0.02 and ≤ 2 mm, ≥ 30% (by grain count) volcanic glass, glassy aggregates, other glass-coated primary minerals or glasses resulting from industrial processes; ***and***
2. no *andic* or *vitric properties*.

Additional information

Tephric material refers to the fine earth, but coarse fragments may also be present (including cinders, lapilli, pumice, pumice-like vesicular pyroclasts, blocks and volcanic bombs). The original description of the tephric material is based on Hewitt (1992), the amendment of *artefacts* is adapted from Uzarowicz et al. (2017).

Relationships with some other diagnostics

Progressive weathering of tephric material will lead to the formation of *vitric properties*. Glasses resulting from industrial processes fulfil the criteria of *artefacts*.

4 Key to the Reference Soil Groups with lists of principal and supplementary qualifiers

Before using the key, please read the 'Rules for naming soils' (Chapter 2).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Soils having one or more of the following: 1. *organic material* starting ≤ 40 cm from the soil surface and having within 100 cm of the soil surface a combined thickness of: a. ≥ 40 cm if < 75% (by volume, related to the fine earth plus all dead plant residues) consists of moss fibres; *or* b. ≥ 60 cm; *or* 2. *organic material* starting at the soil surface, having a thickness of ≥ 10 cm and directly overlying ice, *continuous rock* or *technic hard material*; *or* 3. a layer of coarse fragments that, together with overlying *organic material*, if present, starts at the soil surface and has a thickness of a. ≥ 10 cm if overlying *continuous rock* or *technic hard material*; *or* b. ≥ 40 cm; and the major part of the interstices between the coarse fragments is filled with *organic material* and the remaining interstices, if present, are void. **HISTOSOLS**	Muusic/ Rockic/ Mawic Cryic Thionic Folic Floatic Subaquatic/ Tidalic Fibric/ Hemic/ Sapric Leptic/ Thyric Murshic/ Drainic Ombric/ Rheic Coarsic Skeletic Andic Vitric	Alcalic/ Dystric/ Eutric Aric Bryic Dolomitic/ Calcaric Fluvic Gelic Hyperorganic Isolatic Lignic Limnic Limonic Mineralic Mulmic Ornithic Placic Pyric Relocatic Salic Sulfidic Technic/ Kalaic Tephric Toxic Transportic Turbic Wapnic

Overview of Key to Reference Soil Groups									
Histosols	**95**	Solonchaks	102	Nitisols	109	Gypsisols	116	Cambisols	123
Anthrosols	96	Gleysols	103	Ferralsols	110	Calcisols	117	Fluvisols	124
Technosols	97	Andosols	104	Chernozems	111	Retisols	118	Arenosols	125
Cryosols	98	Podzols	105	Kastanozems	112	Acrisols	119	Regosols	126
Leptosols	99	Plinthosols	106	Phaeozems	113	Lixisols	120		
Solonetz	100	Planosols	107	Umbrisols	114	Alisols	121		
Vertisols	101	Stagnosols	108	Durisols	115	Luvisols	122		

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *hortic*, *irragric*, *plaggic* or *terric horizon*, ≥ 50 cm thick; *or* 2. an *anthraquic horizon* and an underlying *hydragric horizon* with a combined thickness of ≥ 50 cm; *or* 3. a *pretic horizon*, the layers of which have a combined thickness of ≥ 50 cm, within 100 cm of the mineral soil surface. **ANTHROSOLS**	Hydragric/ Irragric/ Hortic/ Plaggic/ Pretic/Terric Gleyic Stagnic Ferralic/ Sideralic Andic	Arenic/ Clayic/ Loamic/ Siltic Acric/ Lixic/ Alic/ Luvic Alcalic/ Dystric/ Eutric Calcic Carbonic Dolomitic/ Calcaric Drainic Escalic Fluvic Glossic/ Retic Endoleptic/ Endothyric Novic Oxyaquic Panpaic Pyric Salic Skeletic Sodic Spodic Technic/ Kalaic Toxic Vertic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers	
Other soils: 1. with all of the following: a. one or both of the following: i. having ≥ 20% (by volume, weighted average, related to the whole soil) *artefacts* in the upper 100 cm from the soil surface or to a limiting layer, whichever is shallower; *or* ii. having a layer, ≥ 10 cm thick and starting ≤ 50 cm from the soil surface, with ≥ 80% (by volume, weighted average, related to the whole soil) *artefacts*; *and* b. not having a layer containing *artefacts* that qualifies as an *argic, duric, ferralic, ferric, fragic, hydragric, natric, nitic, petrocalcic, petroduric, petrogypsic, petroplinthic, pisoplinthic, plinthic, spodic* or *vertic horizon* starting ≤ 100 cm from the soil surface, unless buried; *and* c. not having a limiting layer, unless consisting of *artefacts*, starting ≤ 10 cm from the soil surface; *or* 2. having a continuous, very slowly permeable to impermeable, constructed geomembrane of any thickness or *technic hard material* starting ≤ 100 cm from the soil surface. **TECHNOSOLS**[1]	Ekranic/ Thyric LinicUrbic Spolic Garbic Cryic Isolatic Leptic Subaquatic/ Tidalic Reductic Coarsic Gleyic Stagnic Andic	Arenic/ Clayic/ Loamic/ Siltic Geoabruptic Alcalic/ Dystric/ Eutric Anthraquic/ Irragric/ Hortic/ Plaggic/ Pretic/ Terric Archaic Calcic Cambic Carbonic Chernic/ Mollic/ Umbric Densic Dolomitic/ Calcaric Drainic Ferritic Fluvic Folic/ Histic Fractic Gelic Gypsic Gypsiric Humic/ Ochric Hyperartefactic Immissic Laxic Lignic Limnic Magnesic Mahic Novic Oxyaquic Panpaic/ Raptic Protic Pyric Relocatic Salic Sideralic Skeletic Sodic Solimovic Protospodic	Sulfidic Tephric Thionic Toxic Transportic Vitric

[1] Technosols may bury other soils, which can be mentioned behind the Technosol classification using the word 'over' in between (see Chapter 2.4). Alternatively, buried diagnostic horizons or buried layers with a diagnostic property can be indicated with the Thapto- specifier followed by a qualifier. The soil material above a geomembrane or *technic hard material* may also be characterized by qualifiers. If the thickness or depth criteria of these qualifiers are not met, the Supra- specifier can be used (see Chapter 2.3.2).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *cryic horizon* starting ≤ 100 cm from the soil surface; *or* 2. a *cryic horizon* starting ≤ 200 cm from the soil surface *and* evidence of cryogenic alteration (cryoturbation, frost heave, cryogenic sorting, thermal cracking, ice segregation, patterned ground, etc.) in some layer within 100 cm of the soil surface. **CRYOSOLS**	Glacic Turbic Subaquatic/ Tidalic/ Reductaquic/ Oxyaquic Leptic Histic Andic Mollic/ Umbric Natric Salic Spodic Retic Alic/ Luvic Calcic/ Wapnic Yermic Protic Cambic Coarsic Skeletic Haplic	Arenic/ Clayic/ Loamic/ Siltic Abruptic Albic Alcalic/ Dystric/ Eutric Biocrustic Dolomitic/ Calcaric Drainic Epic/ Endic/ Dorsic Evapocrustic/ Puffic Fluvic Folic Gypsiric Humic/ Ochric Limnic Magnesic Nechic Novic Ornithic Pyric Raptic Sodic Sulfidic Technic/ Kalaic Tephric Thixotropic Toxic Transportic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers

Other soils having:
1. one of the following:
    a. *continuous rock* starting ≤ 25 cm from the soil surface; *or*
    b. < 20% (by volume, related to the whole soil) fine earth plus dead plant residues of any size[2], averaged over a depth of 75 cm from the soil surface or to *continuous rock*, whichever is shallower;
    and
2. no *duric, petrocalcic, petroduric, petrogypsic, pisoplinthic* or *spodic horizon*.
 	
LEPTOSOLS
	Nudilithic/ Lithic
	Coarsic
	Skeletic
	Subaquatic/ Tidalic
	Histic
	Andic
	Rendzic/ Mollic/ Umbric
	Gypsic
	Calcic
	Cambic/ Brunic
	Yermic/ Takyric
	Folic
	Gypsiric
	Dolomitic/ Calcaric
	Dystric/ Eutric
		Arenic/ Clayic/ Loamic/ Siltic
		Aeolic
		Aric
		Biocrustic
		Drainic
		Fluvic
		Gelic
		Gleyic
		Humic/ Ochric
		Isolatic
		Lapiadic
		Magnesic
		Nechic
		Novic
		Ornithic
		Oxyaquic
		Panpaic/ Raptic
		Placic
		Protic
		Pyric
		Salic
		Sodic
		Solimovic
		Protospodic
		Stagnic
		Sulfidic
		Technic/ Kalaic
		Tephric
		Toxic
		Transportic
		Turbic
		Protovertic
		Vitric

Overview of Key to Reference Soil Groups

[2] The volume occupied neither by fine earth nor by dead plant residues is occupied by coarse fragments, remnants of broken-up cemented layers > 2 mm, *artefacts* > 2 mm, or interstices.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *natric horizon* starting ≤ 100 cm from the mineral soil surface. **SOLONETZ**	Abruptic Gleyic Stagnic Mollic Salic Gypsic Petrocalcic Calcic Vertic Yermic/ Takyric Nudinatric Albic Haplic	Arenic/ Clayic/ Loamic/ Siltic Aeolic Biocrustic Neocambic/ Neobrunic Chromic Columnic Cutanic Differentic Duric Epic/ Endic Ferric Fluvic Fractic Humic/ Ochric Magnesic Hypernatric Novic Oxyaquic Petroplinthic Pyric Raptic Retic Skeletic Technic/ Kalaic Toxic Transportic Turbic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *vertic horizon* starting ≤ 100 cm from the mineral soil surface; *and* 2. ≥ 30% clay between the mineral soil surface and the *vertic horizon* throughout; *and* 3. *shrink-swell cracks* that start: a. at the mineral soil surface; *or* b. at the base of a plough layer; *or* c. directly below a layer with strong granular structure or strong angular or subangular blocky structure with an aggregate size of ≤ 1 cm (self-mulching surface); *or* d. directly below a surface crust; *and* extend to the *vertic horizon*. **VERTISOLS**	Salic Sodic Leptic Petroduric/ Duric Gypsic Petrocalcic Calcic Hydragric/ Anthraquic/ Irragric Pellic Chromic Haplic	Alcalic/ Endodystric Aric Chernic/ Mollic Dolomitic/ Calcaric Drainic Hypereutric Epic/ Endic Ferric Fractic Gilgaic Gleyic Grumic/ Mazic/ Pelocrustic Gypsiric Humic/ Ochric Magnesic Novic Oxyaquic Pyric Raptic Skeletic Stagnic Sulfidic Takyric Technic/ Kalaic Thionic Toxic Transportic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils: 1. having a *salic horizon* starting ≤ 50 cm from the soil surface; *and* 2. not having a *thionic horizon* starting ≤ 50 cm from the soil surface; *and* 3. not being permanently submerged by water and not located below the line affected by tidal water (i.e. not located below the line of mean high water springs). **SOLONCHAKS**	Petrosalic Gleyic Stagnic Sodic Petrogypsic Gypsic Petrocalcic Calcic Leptic Mollic Fluvic Yermic/ Takyric Haplic	Arenic/ Clayic/ Loamic/ Siltic Aceric Aeolic Alcalic Biocrustic Carbonatic/ Chloridic/ Sulfatic Densic Dolomitic/ Calcaric Drainic Duric Evapocrustic/ Puffic Folic/ Histic Fractic Gelic Gypsiric Humic/ Ochric Magnesic Novic Oxyaquic Panpaic/ Raptic Pyric Hypersalic Skeletic Solimovic Sulfidic Technic/ Kalaic Endothionic Toxic Transportic Turbic Vertic

Key to the Reference Soil Groups	**Principal qualifiers**	**Supplementary qualifiers**
Other soils having one or more of the following: 1. a layer, $\geq$ 25 cm thick and starting $\leq$ 40 cm from the mineral soil surface, that has a. *gleyic properties* throughout; *and* b. *reducing conditions* in some parts of every sublayer; *or* 2. both of the following: a. a *mollic* or *umbric horizon*, > 40 cm thick, that has *reducing conditions* in some parts of every sublayer, from 40 cm below the mineral soil surface to the lower limit of the *mollic* or *umbric horizon*; *and* b. directly underneath the *mollic*/*umbric horizon*, a layer, $\geq$ 10 cm thick, that has its lower limit $\geq$ 65 cm below the mineral soil surface, and that has: i. *gleyic properties* throughout; *and* ii. *reducing conditions* in some parts of every sublayer; *or* 3. permanent saturation by water starting $\leq$ 40 cm from the mineral soil surface. **GLEYSOLS**	Thionic Reductic Subaquatic/ Tidalic Hydragric/ Anthraquic/ Irragric/ Hortic/ Plaggic/ Pretic/ Terric Histic Andic Vitric Chernic/ Mollic/ Umbric Pisoplinthic/ Plinthic Stagnic Oxyaquic Oxygleyic/ Reductigleyic Gypsic Calcic/ Wapnic Spodic Fluvic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Abruptic Acric/ Lixic/ Alic/ Luvic Alcalic Arenicolic Aric Drainic Ferralic/ Sideralic Folic Fractic Gelic Humic/ Ochric Inclinic Laxic Limnic Limonic Magnesic Mulmic Nechic Novic Placic Pyric Raptic Relocatic Salic Skeletic Sodic Solimovic Sulfidic Takyric Technic/ Kalaic Tephric Toxic Transportic Turbic Uterquic Vertic

Overview of Key to Reference Soil Groups

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. one or more layers with *andic* or *vitric properties* with a combined thickness of: a. ≥ 30 cm, within 100 cm of the soil surface and starting ≤ 25 cm from the soil surface; *or* b. ≥ 60% of the entire thickness of the soil, if a limiting layer starts > 25 and ≤ 50 cm from the soil surface; *and* 2. no *argic*, *ferralic*, *petroplinthic*, *pisoplinthic*, *plinthic* or *spodic horizon* starting ≤ 100 cm of the soil surface, unless buried deeper than 50 cm from the mineral soil surface. **ANDOSOLS**[3]	Aluandic/ Silandic Vitric Leptic Hydragric/ Anthraquic Gleyic Hydric Histic Chernic/ Mollic/ Umbric Petroduric/ Duric Gypsic Calcic Tephric Aeolic Skeletic Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Protoandic Aric Dolomitic/ Calcaric Drainic Eutrosilic/ Acroxic Fluvic Folic Fragic Gelic Humic/ Ochric Mulmic Nechic Novic Oxyaquic Panpaic Placic Posic Pyric Reductic Sideralic Sodic Solimovic Protospodic Technic/ Kalaic Thixotropic Toxic Transportic Turbic

[3] Andosols may bury other soils, which can be mentioned behind the Andosol classification using the word 'over' in between (see Chapter 2.4). Alternatively, buried diagnostic horizons or buried layers with a diagnostic property can be indicated with the Thapto- specifier followed by a qualifier.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *spodic horizon* starting ≤ 200 cm from the mineral soil surface. **PODZOLS**	Ortsteinic Carbic/ Rustic Albic/ Entic Leptic Hortic/ Plaggic/ Pretic/ Terric Histic Gleyic Andic Vitric Stagnic Anthromollic/ Umbric Glossic/ Retic Acric/ Alic Coarsic Skeletic	Arenic/ Loamic/ Siltic Abruptic Aric Neocambic/ Neobrunic Cordic Densic Drainic Epic/ Endic/ Dorsic Eutric Folic Fragic Gelic Limonic Novic Ornithic Oxyaquic Placic Pyric Raptic Sideralic Hyperspodic Technic/ Kalaic Toxic Transportic Turbic

Overview of Key to Reference Soil Groups

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *plinthic*, *pisoplinthic* or *petroplinthic horizon* starting ≤ 100 cm from the mineral soil surface. **PLINTHOSOLS**	Petric Pisoplinthic Gibbsic Stagnic Geric Nitic Histic Mollic/ Umbric Albic Leptic Coarsic Skeletic Haplic	Arenic/ Clayic/ Loamic/ Siltic Abruptic Acric/ Lixic Aric Cohesic Drainic Duric Dystric/ Eutric Epic/ Endic Folic Humic/ Ochric Isopteric Magnesic Novic Oxyaquic Posic Pyric Raptic Saprolithic Technic/ Kalaic Toxic Transportic

Key to the Reference Soil Groups	**Principal qualifiers**	**Supplementary qualifiers**
Other soils having an *abrupt textural difference* ≤ 75 cm from the mineral soil surface and having within the range of 5 cm directly above or below the *abrupt textural difference*: 1. *stagnic properties*, in which the area of reductimorphic features plus the area of oximorphic features is ≥ 50% (weighted average, related to the fine earth plus oximorphic features of any size and any cementation class) of the total area; *and* 2. *reducing conditions* for some time during the year in some parts of the soil volume that has the reductimorphic features. **PLANOSOLS**	Reductic Thionic Leptic Hydragric/ Anthraquic/ Irragric/ Hortic/ Plaggic/ Pretic/ Terric Histic Gleyic Chernic/ Mollic/ Umbric Albic Fluvic Vertic Glossic/ Retic Acric/ Lixic/ Alic/ Luvic Petroduric/ Duric Calcic Dolomitic/ Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Alcalic Andic Aric Cambic Capillaric Chromic Cohesic Columnic Densic Drainic Ferralic/ Sideralic Ferric Folic Fragic Gelic Gelistagnic Geric Humic/ Ochric Inclinic Magnesic Mochipic Nechic Novic Pyric Raptic Skeletic Sodic Solimovic Sulfidic Technic/ Kalaic Toxic Transportic Turbic Uterquic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. *stagnic properties*, in which the area of reductimorphic features plus the area of oximorphic features is ≥ one third (weighted average, related to the fine earth plus oximorphic features of any size and any cementation class) of the area from the mineral soil surface to a depth of 60 cm or to *continuous rock*, whichever is shallower; *and* 2. *reducing conditions* for some time during the year in some parts of the soil volume that has the reductimorphic features within 60 cm from the mineral soil surface or to *continuous rock*, whichever is shallower. **STAGNOSOLS**	Reductic Thionic Leptic Hydragric/ Anthraquic/ Irragric/ Hortic/ Plaggic/ Pretic/ Terric Histic Gleyic Chernic/ Mollic/ Umbric Albic Fluvic Vertic Glossic/ Retic Acric/ Lixic/ Alic/ Luvic Calcic Dolomitic/ Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Endoabruptic Alcalic Aric Cambic Capillaric Cohesic Drainic Ferralic/ Sideralic Ferric Folic Fragic Gelic Gelistagnic Geric Humic/ Ochric Inclinic Magnesic Mochipic Nechic Nitic Novic Ornithic Pyric Raptic Rhodic/ Chromic Skeletic Sodic Solimovic Protospodic Sulfidic Technic/ Kalaic Toxic Transportic Turbic Uterquic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *nitic horizon* starting ≤ 100 cm from the mineral soil surface; *and* 2. from the mineral soil surface to the *nitic horizon*, a clay content that is at least half of the weighted average clay content of the *nitic horizon*; *and* 3. no *vertic horizon* starting above or at the upper limit of the *nitic horizon*. **NITISOLS**	Ferralic/ Sideralic Ferritic Leptic Rhodic/ Xanthic Geric Hydragric/ Anthraquic/ Pretic Profundihumic Mollic/ Umbric Acric/ Lixic/ Alic/ Luvic Dystric/ Eutric	Andic Aric Densic Epic/ Endic Ferric Endogleyic Humic/ Ochric Magnesic Novic Oxyaquic Posic Pyric Raptic Sodic Endostagnic Technic/ Kalaic Toxic Transportic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *ferralic horizon* starting ≤ 150 cm from the mineral soil surface; *and* 2. no *argic horizon* starting above or at the upper limit of the *ferralic horizon*, unless the *argic horizon* has, in its upper 30 cm or throughout, whichever is shallower, one or more of the following: a. < 10% water-dispersible clay; *or* b. a ΔpH (pH_{KCl} - pH_{water}) ≥ 0 (both in 1:1 solution); *or* c. ≥ 1.4% *soil organic carbon*. **FERRALSOLS**	Ferritic Gibbsic Rhodic/ Xanthic Geric Nitic Pretic Gleyic Stagnic Profundihumic Mollic/ Umbric Acric/ Lixic Skeletic Haplic	Arenic/ Clayic/ Loamic/ Siltic Abruptic Activic Andic Aric Cohesic Densic Dystric/ Eutric Epic/ Endic/ Dorsic Ferric Fluvic Folic Humic/ Ochric Isopteric Litholinic Novic Oxyaquic Posic Pyric Raptic Saprolithic Solimovic Sombric Technic/ Kalaic Toxic Transportic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *chernic horizon*; *and* 2. starting ≤ 50 cm below the lower limit of the *mollic*[4] *horizon* and, if present, above a *petrocalcic horizon,* a layer with *protocalcic properties*, ≥ 5 cm thick, or a *calcic horizon*; *and* 3. a base saturation (by 1 *M* NH_4OAc, pH 7)[5] of ≥ 50% from the mineral soil surface to the layer with *protocalcic properties* or to the *calcic horizon*, throughout. **CHERNOZEMS**	Petroduric/ Duric Petrocalcic Leptic Hortic Gleyic Vertic Greyzemic Luvic Calcic Cambic Skeletic Vermic Tonguic Haplic	Arenic/ Clayic/ Loamic/ Siltic Andic Aric Densic Fluvic Fractic Humic Novic Oxyaquic Pachic Pyric Raptic Salic Sodic Solimovic Sombric Stagnic Technic/ Kalaic Tephric Transportic Turbic Vitric

Overview of Key to Reference Soil Groups

[4] Any *chernic horizon* also meets the criteria of a *mollic* horizon. The *mollic horizon* may extend below the *chernic horizon*.
[5] If the data for base saturation are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *mollic horizon*; *and* 2. starting ≤ 70 cm of the mineral soil surface and, if present, above a *petrocalcic horizon,* a layer with *protocalcic properties*, ≥ 5 cm thick, or a *calcic horizon*; *and* 3. a base saturation (by 1 *M* NH_4OAc, pH 7)[6] of ≥ 50% from the mineral soil surface to the layer with *protocalcic properties* or to the *calcic horizon*, throughout. **KASTANOZEMS**	Someric Petroduric/ Duric Petrogypsic Gypsic Petrocalcic Leptic Hortic/ Terric Gleyic Fluvic Vertic Luvic Calcic Cambic/ Brunic Skeletic Tonguic Haplic	Arenic/ Clayic/ Loamic/ Siltic Andic Anthric Aric Chromic Densic Fractic Gelic Humic Laxic Magnesic Novic Oxyaquic Pachic Panpaic/ Raptic Pyric Salic Sodic Solimovic Sombric Stagnic Technic/ Kalaic Tephric Transportic Turbic Vitric

[6] If the data for base saturation are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *mollic horizon*; *and* 2. a base saturation (by 1 *M* NH_4OAc, pH 7)[7] of ≥ 50% throughout to a depth of 100 cm from the mineral soil surface or to a limiting layer, whichever is shallower. **PHAEOZEMS**	Rendzic Chernic/ Someric Mulmic Petroduric/ Duric Petrocalcic Endocalcic Leptic Irragric/ Hortic/ Pretic/ Terric Gleyic Stagnic Fluvic Vertic Greyzemic Glossic/ Retic Lixic/ Luvic Cambic/ Brunic Skeletic Vermic Tonguic Gypsiric Dolomitic/ Calcaric Haplic	Arenic/ Clayic/ Loamic/ Siltic Abruptic Albic Andic Anthric Aric Columnic Densic Ferralic/ Sideralic Folic Fractic Humic Isolatic Laxic Limonic Magnesic Nechic Novic Oxyaquic Pachic Panpaic/ Raptic Pyric Relocatic Rhodic/ Chromic Salic Sodic Solimovic Sombric Technic/ Kalaic Tephric Transportic Turbic Vitric

[7] If the data for base saturation are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *umbric* or *mollic* or *hortic horizon*. **UMBRISOLS**	Hortic/ Plaggic/ Pretic/ Terric Chernic/ Mollic/ Someric Mulmic Fragic Leptic Gleyic Stagnic Fluvic Greyzemic Glossic/ Retic Acric/ Lixic/ Alic/ Luvic Cambic/ Brunic Skeletic Tonguic Endodolomitic/ Endocalcaric Haplic	Arenic/ Clayic/ Loamic/ Siltic Abruptic Albic Andic Anthric Aric Densic Drainic Hyperdystric/ Eutric Ferralic/ Sideralic Folic Gelic Humic Isolatic Laxic Limonic Nechic Novic Ornithic Oxyaquic Pachic Panpaic/ Raptic Placic Pyric Relocatic Rhodic/ Chromic Solimovic Sombric Protospodic Sulfidic Technic/ Kalaic Thionic Toxic Transportic Turbic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having a *petroduric* or *duric horizon* starting ≤ 100 cm from the mineral soil surface. **DURISOLS**	Petric Petrogypsic Gypsic Petrocalcic Calcic Leptic Acric/ Lixic/ Alic/ Luvic Cambic Coarsic Fractic Skeletic Yermic/ Takyric Andic Gypsiric Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Aeolic Aric Biocrustic Chromic Cohesic Epic/ Endic Gleyic Humic/ Ochric Isopteric Magnesic Novic Pyric Raptic Salic Sideralic Sodic Stagnic Technic/ Kalaic Toxic Transportic Vertic

<table>
<tr><th>Key to the Reference Soil Groups</th><th>Principal qualifiers</th><th>Supplementary qualifiers</th></tr>
<tr><td>Other soils having:
1. a gypsic or petrogypsic horizon starting ≤ 100 cm from the mineral soil surface; and
2. no argic horizon starting above or at the upper limit of the gypsic or petrogypsic horizon, unless the argic horizon contains secondary gypsum or secondary carbonates, throughout.

GYPSISOLS</td><td>Petric
Petrocalcic
Calcic
Leptic
Gleyic
Stagnic
Lixic/ Luvic
Cambic
Coarsic
Fractic
Skeletic
Yermic/ Takyric
Calcaric
Haplic</td><td>Arenic/ Clayic/ Loamic/ Siltic
Abruptic
Aeolic
Aric
Biocrustic
Epic/ Endic
Fluvic
Hypergypsic
Humic/ Ochric
Isopteric
Naramic
Novic
Panpaic/ Raptic
Pyric
Salic
Sodic
Technic/ Kalaic
Toxic
Transportic
Turbic
Vertic</td></tr>
</table>

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. a *calcic* or *petrocalcic horizon* starting ≤ 100 cm from the mineral soil surface; *and* 2. no *argic horizon* starting above or at the upper limit of the *calcic* or *petrocalcic horizon* unless the *argic horizon* contains secondary carbonates, throughout. **CALCISOLS**	Petric Leptic Gleyic Stagnic Lixic/ Luvic Cambic Coarsic Fractic Skeletic Yermic/ Takyric Gypsiric Haplic	Arenic/ Clayic/ Loamic/ Siltic Abruptic Aeolic Aric Biocrustic Hypercalcic Densic Epic/ Endic Fluvic Gelic Protogypsic Humic/ Ochric Isopteric Magnesic Naramic Novic Panpaic/ Raptic Pyric Rhodic/ Chromic Salic Sodic Solimovic Technic/ Kalaic Toxic Transportic Turbic Vertic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *argic horizon* starting ≤ 100 cm from the mineral soil surface and having *retic properties* at its upper boundary. **RETISOLS**	Abruptic Fragic Glossic Leptic Plaggic/ Pretic/ Terric Histic Gleyic Stagnic Sideralic Nudiargic Neocambic/ Neobrunic Albic Calcic Skeletic Endodolomitic/ Endocalcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Aric Cutanic Densic Differentic Drainic Epic/ Endic Folic Gelic Humic/ Ochric Lamellic Nechic Novic Oxyaquic Profondic Pyric Raptic Solimovic Protospodic Technic/ Kalaic Toxic Transportic Turbic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. an *argic horizon* starting ≤ 100 cm from the mineral soil surface; *and* 2. a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some subhorizon of the *argic horizon* within 150 cm of the mineral soil surface; *and* 3. exchangeable Al > exchangeable (Ca+Mg+K+Na)[8] in half or more of: a. the depth range between 50 and 100 cm of the mineral soil surface; *or* b. the lower half of the mineral soil above a limiting layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower. **ACRISOLS**	Abruptic Fragic Leptic Hydragric/ Anthraquic/ Pretic/ Terric Gleyic Stagnic Ferralic Rhodic/ Chromic/ Xanthic Nudiargic Lamellic Albic Ferric Skeletic Haplic	Arenic/ Clayic/ Loamic/ Siltic Andic Aric Neocambic/ Neobrunic Cohesic Cutanic Densic Differentic Hyperdystric/ Epieutric Epic/ Endic Geric Gibbsic Humic/ Ochric Magnesic Nechic Nitic Novic Oxyaquic Posic Profondic Pyric Raptic Saprolithic Sodic Solimovic Sombric Technic/ Kalaic Toxic Transportic Vitric

Overview of Key to Reference Soil Groups

[8] Exchangeable cations are given in $cmol_c$ kg^{-1}. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. an *argic horizon* starting ≤ 100 cm from the mineral soil surface; *and* 2. a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some subhorizon of the *argic horizon* within 150 cm of the mineral soil surface. **LIXISOLS**	Abruptic Fragic Petrocalcic Leptic Hydragric/ Anthraquic/ Pretic/ Terric Gleyic Stagnic Ferralic Rhodic/ Chromic/ Xanthic Nudiargic Lamellic Albic Ferric Gypsic Calcic Yermic/ Takyric Skeletic Haplic	Arenic/ Clayic/ Loamic/ Siltic Andic Aric Neocambic/ Neobrunic Cohesic Columnic Cutanic Densic Differentic Epidystric/ Hypereutric Epic/ Endic Fractic Geric Gibbsic Humic/ Ochric Magnesic Nechic Nitic Novic Oxyaquic Profondic Pyric Raptic Saprolithic Sodic Solimovic Technic/ Kalaic Toxic Transportic Vitric

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having: 1. an *argic horizon* starting ≤ 100 cm from the mineral soil surface; *and* 2. exchangeable Al > exchangeable (Ca+Mg+K+Na)[9] in half or more of: a. the depth range between 50 and 100 cm of the mineral soil surface; *or* b. the lower half of the mineral soil above a limiting layer starting ≤ 100 cm from the mineral soil surface whichever is shallower. **ALISOLS**	Abruptic Fragic Leptic Hydragric/ Anthraquic/ Plaggic/ Pretic/ Terric Gleyic Stagnic Vertic Rhodic/ Chromic Nudiargic Lamellic Albic Ferric Skeletic Haplic	Arenic/ Clayic/ Loamic/ Siltic Andic Aric Neocambic/ Neobrunic Cutanic Densic Differentic Hyperdystric/ Epieutric Epic/ Endic Fluvic Folic Gelic Humic/ Ochric Hyperalic Magnesic Nechic Nitic Novic Oxyaquic Profondic Pyric Raptic Sodic Solimovic Protospodic Technic/ Kalaic Toxic Transportic Turbic Vitric

Overview of Key to Reference Soil Groups

[9] Exchangeable cations are given in $cmol_c\ kg^{-1}$. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having an *argic horizon* starting ≤ 100 cm from the mineral soil surface. **LUVISOLS**	Abruptic Fragic Petrocalcic Leptic Hydragric/ Anthraquic/ Irragric/ Pretic/ Terric Gleyic Stagnic Vertic Rhodic/ Chromic Nudiargic Lamellic Albic Ferric Gypsic Calcic Yermic/ Takyric Skeletic Dolomitic/ Calcaric Haplic	Arenic/ Clayic/ Loamic/ Siltic Andic Aric Neocambic /Neobrunic Columnic Cutanic Densic Differentic Epidystric/ Hypereutric Epic/ Endic Escalic Fluvic Fractic Gelic Humic/ Ochric Magnesic Nechic Nitic Novic Oxyaquic Profondic Pyric Raptic Sodic Solimovic Technic/ Kalaic Toxic Transportic Turbic Vitric

Key to the Reference Soil Groups	**Principal qualifiers**	**Supplementary qualifiers**
Other soils having: 1. a *cambic horizon* a. starting ≤ 50 cm from the mineral soil surface; *and* b. having its lower limit ≥ 25 cm from the mineral soil surface; *or* 2. an *anthraquic*, *hydragric*, *irragric*, *plaggic, pretic* or *terric horizon*; *or* 3. a *fragic*, *thionic* or *vertic horizon* starting ≤ 100 cm from the mineral soil surface; *or* 4. a *tsitelic horizon* with a texture class of sandy loam or finer, starting ≤ 50 cm from the mineral soil surface; *or* 5. one or more layers with *andic* or *vitric properties* with a combined thickness of ≥ 15 cm within 100 cm of the soil surface. **CAMBISOLS**	Fragic Thionic Hydragric/ Anthraquic/ Irragric/ Plaggic/ Pretic/ Terric Tsitelic Vertic Andic Vitric Leptic Histic Gleyic Stagnic Solimovic Fluvic Sideralic Rhodic/ Chromic Skeletic Yermic/ Takyric Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Geoabruptic Aeolic Alcalic Aric Biocrustic Protocalcic Carbonic Cohesic Columnic Densic Drainic Escalic Ferric Folic Fractic Gelic Gelistagnic Protogypsic Humic/ Ochric Isopteric Laxic Limonic Litholinic Magnesic Nechic Novic Ornithic Oxyaquic Panpaic/ Raptic Pyric Salic Saprolithic Sodic Protospodic Sulfidic Technic/ Kalaic Tephric Toxic Transportic Turbic

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having *fluvic material*: 1. ≥ 25 cm thick and starting ≤ 25 cm from the mineral soil surface; *or* 2. from the lower limit of a plough layer, ≤ 40 cm thick, to a depth of ≥ 50 cm from the mineral soil surface. **FLUVISOLS**[10]	Tidalic Pantofluvic/ Anofluvic/ Orthofluvic Leptic Histic Gleyic Stagnic Skeletic Tephric Yermic/ Takyric Protic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Geoabruptic Alcalic Arenicolic Aric Protocalcic Densic Drainic Folic Gelic Humic/ Ochric Limnic Limonic Magnesic Nechic Oxyaquic Panpaic Placic Pyric Salic Sideralic Sodic Sulfidic Technic/ Kalaic Toxic Transportic Turbic Protovertic

[10] Fluvisols may bury other soils, which can be mentioned behind the Fluvisol classification using the word 'over' in between (see Chapter 2.4). Alternatively, buried diagnostic horizons or buried layers with a diagnostic property can be indicated with the Thapto- specifier followed by a qualifier.

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils having within 100 cm of the mineral soil surface: 1. a weighted average texture class of loamy sand or sand; *and* 2. layers of finer texture, if present, with a combined thickness of < 15 cm; *and* 3. layers with ≥ 40% (by volume, related to the whole soil) coarse fragments, if present, with a combined thickness of < 15 cm. **ARENOSOLS**[11]	Tidalic Aeolic Solimovic Tephric Tsitelic Brunic Gleyic Sideralic Yermic Protic Transportic Relocatic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Geoabruptic Alcalic Arenicolic Aric Biocrustic Protocalcic Carbonic Cordic Folic Gelic Protogypsic Humic/ Ochric Hydrophobic Isopteric Lamellic/ Protoargic Limonic Nechic Novic Ornithic Oxyaquic Panpaic/ Raptic Placic Pyric Rhodic/ Chromic/ Rubic/ Claric Salic Sodic Bathyspodic Protospodic Stagnic Sulfidic Technic/ Kalaic Toxic Turbic

Overview of Key to Reference Soil Groups

[11] Arenosols may bury other soils, which can be mentioned behind the Arenosol classification using the word 'over' in between (see Chapter 2.4). Alternatively, buried diagnostic horizons or buried layers with a diagnostic property can be indicated with the Thapto- specifier followed by a qualifier. Arenosols may have diagnostic horizons at depths of > 100 cm. These can be indicated with the Bathy- specifier followed by a qualifier, e.g. Bathyacric (> 100 cm), Bathyspodic (> 200 cm).

Key to the Reference Soil Groups	Principal qualifiers	Supplementary qualifiers
Other soils: **REGOSOLS**	Tidalic Leptic Solimovic Aeolic Tephric Brunic Gleyic Stagnic Skeletic Vermic Yermic/ Takyric Protic Transportic Relocatic Gypsiric Dolomitic/ Calcaric Dystric/ Eutric	Arenic/ Clayic/ Loamic/ Siltic Geoabruptic Alcalic Aric Biocrustic Protocalcic Carbonic Cordic Densic Drainic Escalic Fluvic Folic Gelic Gelistagnic Protogypsic Humic/ Ochric Isolatic Isopteric Magnesic Nechic Ornithic Oxyaquic Panpaic/ Raptic Pyric Salic Saprolithic Sodic Technic/ Kalaic Toxic Turbic Protovertic

5 Definitions of qualifiers

Before using the qualifiers, please read the 'Rules for naming soils' (Chapter 2).

The definitions of the qualifiers for the second-level units relate to RSGs, diagnostic horizons, properties and materials, and to attributes such as colour, chemical conditions, texture, etc. References to the RSGs defined in Chapter 4 and the diagnostics listed in Chapter 3 are shown *in italics*.
Usually, only a limited number of combinations will be possible in a soil name; many of the definitions make the qualifiers mutually exclusive.

General rules

1. **Subqualifiers** (see Chapter 2.3), **which may be used in the soil name instead of the qualifier listed in the Key** (Chapter 4), are found beneath the definition of the respective qualifier (e.g. Protocalcic is found under Calcic). **Subqualifiers, which cannot replace a listed qualifier,** are found in alphabetical order (e.g. Hyperalic).
2. If a subqualifier related to depth requirements can be constructed by the user, **the figure indicates, which rule applies**: (1), (2), (3), (4), (5). If no figure is indicated, these subqualifiers cannot be constructed.

Definitions

Abruptic (ap) (from Latin *abruptus*, broken away): having an *abrupt textural difference* within 100 cm of the mineral soil surface (1).

Geoabruptic (go) (from Greek *gaia*, earth): having an *abrupt textural difference* within 100 cm of the mineral soil surface that is not associated with the upper limit of an *argic*, *natric* or *spodic horizon* (1).

Aceric (ae) (from Latin *acer*, sharp): having within 100 cm of the soil surface a layer with a pH (1:1 in water) between ≥ 3.5 and < 5 and jarosite concentrations (*in Solonchaks only*) (2).

Acric (ac) (from Latin *acer*, sharp): having an *argic horizon* starting ≤ 100 cm from the mineral soil surface with a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some subhorizon within 150 cm of the mineral soil surface; and having exchangeable Al > exchangeable (Ca+Mg+K+Na) in half or more of the depth range between 50 and 100 cm of the mineral soil surface or the lower half of the mineral soil above a limiting layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).
Note: Exchangeable cations are given in $cmol_c$ kg^{-1}. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Acroxic (ao) (from Latin *acer*, sharp, and Greek *oxys*, sour): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 30 cm, and with < 2 $cmol_c$ kg^{-1} fine earth exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) (*in Andosols only*) (2).

Activic (at) (from Latin *activus*, busy): having above a *ferralic horizon* a layer, ≥ 30 cm thick, with a CEC (by 1 *M* NH_4OAc, pH 7) of ≥ 24 $cmol_c$ kg^{-1} clay and < 0.6% *soil organic carbon* (*in Ferralsols only*) (2).

Aeolic (ay) (from Greek *aiolos*, wind): having *aeolic material* (2: Ano- and Panto- only).

Albic (ab) (from Latin *albus*, white): having an *albic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Alcalic (ax) (from Arabic *al-qali*, salt-containing ash): having:

- in *Histosols*, a pH (1:1 in water) of ≥ 8.5 in the *organic material* within 50 cm of the soil surface,
- in other soils, a pH (1:1 in water) of ≥ 8.5 in the upper 50 cm of the mineral soil surface or to a limiting layer, whichever is shallower,

and fulfilling the set of diagnostic criteria of the Eutric qualifier.

Alic (al) (from Latin *alumen*, alum): having an *argic horizon* starting ≤ 100 cm from the mineral soil surface with a CEC (by 1 *M* NH_4OAc, pH 7) of ≥ 24 $cmol_c$ kg^{-1} clay throughout within 150 cm of the mineral soil surface; and having exchangeable Al > exchangeable (Ca+Mg+K+Na) in half or more of the depth range between 50 and 100 cm of the mineral soil surface or the lower half of the mineral soil above a limiting layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).
Note: Exchangeable cations are given in $cmol_c$ kg^{-1}. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Aluandic (aa) (from Latin *alumen*, alum, and Japanese *an*, dark, and *do*, soil): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 15 cm with *andic properties* and a Si_{ox} content of < 0.6% (*in Andosols only*) (2).

Andic (an) (from Japanese *an*, dark, and *do*, soil): having within 100 cm of the soil surface one or more layers with *andic* or *vitric properties* with a combined thickness of ≥ 30 cm (in *Cambisols* ≥ 15 cm), of which ≥ 15 cm (in *Cambisols* ≥ 7.5 cm) have *andic properties* (2).

Protoandic (qa) (from Greek *proton*, first): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 15 cm, and with an Al_{ox} + ½Fe_{ox} value of ≥ 1.2%, a bulk density of ≤ 1.2 kg dm^{-3} and a phosphate retention of ≥ 55%; and not fulfilling the set of diagnostic criteria of the Andic qualifier (2).

Note: For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined at 105 °C (see Annex 2, Chapter 9.5).

Anthraquic (aq) (from Greek *anthropos*, human being, and Latin *aqua*, water): having an *anthraquic horizon* and no *hydragric horizon*.

Anthric (ak) (from Greek *anthropos*, human being): having *anthric properties*.

Archaic (ah) (from Greek *archae*, beginning): having a layer, ≥ 20 cm thick and within 100 cm of the soil surface, with ≥ 20% (by volume, weighted average, related to the whole soil) *artefacts* containing ≥ 50% (by volume, weighted average, related to the whole soil) *artefacts* produced by pre-industrial processes, e.g. ceramics, showing traces of production by hand, ceramics that can easily be broken or ceramics containing sand (*in Technosols* only) (2).

Arenic (ar) (from Latin *arena*, sand): consisting of *mineral material* and having, single or in combination, a texture class of sand or loamy sand

- in one or more layers with a combined thickness of ≥ 30 cm, occurring within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting > 10 and < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Arenicolic (ad) (related to the worm genus *Arenicola*): having ≥ 50% (by volume, weighted average) of worm holes, worm casts, or filled animal burrows in a layer, ≥ 20 cm thick and occurring in a tidal area.

Aric (ai) (from Latin *arare*, to plough): having a layer, ≥ 10 cm thick and starting at the soil surface, that is homogenized by ploughing and that has an abrupt or very abrupt lower boundary (2: Ano- and Panto- only).

Arzic (az) (from Turkish *arz*, land or earth's crust): saturated by groundwater or flowing water in some layer within 50 cm of the soil surface during some time in most years and containing ≥ 15% gypsum averaged over a depth of 100 cm from the soil surface or to a limiting layer, whichever is shallower (*in Gypsisols only*).

Biocrustic (bc) (from Greek *bios*, life, and Latin and *crusta*, crust): having a biological surface crust.

Brunic (br) (from Low German *brun*, brown): having a layer, ≥ 15 cm thick and starting ≤ 50 cm from the mineral soil surface, that meets diagnostic criteria 3 and 4 of the *cambic horizon* but fails diagnostic criterion 1 and does not consist of *claric material*.

Neobrunic (nb) (from Greek *neos*, new): having a layer, ≥ 15 cm thick and starting ≤ 50 cm from the mineral soil surface, that meets diagnostic criteria 3 and 4 of the *cambic horizon* but fails diagnostic criterion 1, does not consist of *claric material* and overlies:

- an *albic horizon* that overlies an *argic*, a *natric* or a *spodic horizon*, *or*
- a layer with *retic properties*.

Bryic (by) (from Greek *bryon*, moss): ≥ 75% (by volume, related to the fine earth plus all dead plant residues) of the *organic material* within 100 cm of the soil surface consists of moss fibres.

Calcaric (ca) (from Latin *calcarius*, containing lime): having *calcaric material*

- in a layer, ≥ 30 cm thick and within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting < 60 cm from the mineral soil surface;

and not having a *calcic* or a *petrocalcic horizon* starting ≤ 100 cm from the mineral soil surface (2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Calcic (cc) (from Latin *calx*, lime): having a *calcic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Hypercalcic (jc) (from Greek *hyper*, over): having a *calcic horizon* with a calcium carbonate equivalent of ≥ 50% and starting ≤ 100 cm from the mineral soil surface (2).

Protocalcic (qc) (from Greek *proton*, first): having a layer with *protocalcic properties* starting ≤ 100 cm from the mineral soil surface and not having a *calcic* or *petrocalcic horizon* starting ≤ 100 cm from the mineral soil surface (*not in Chernozems and Kastanozems, where protocalcic properties are part of the defintion*) (2).

Cambic (cm) (from Latin *cambire*, to change): having a *cambic horizon*, not consisting of *claric material* and starting ≤ 50 cm from the mineral soil surface.

Neocambic (nc) (from Greek *neos*, new): having a *cambic horizon*, not consisting of *claric material*, starting ≤ 50 cm from the mineral soil surface and overlying:

- an *albic horizon* that overlies an *argic*, a *natric* or a *spodic horizon*, *or*
- a layer with *retic properties*.

Capillaric (cp) (from Latin *capillus*, hair): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that has so few macropores that water saturation of capillary pores causes *reducing conditions*.

Carbic (cb) (from Latin *carbo*, coal): having a *spodic horizon* that has a Munsell colour value of ≤ 2, moist, throughout ('Humus Podzols'; *in Podzols only*).

Carbonatic (cn) (from Latin *carbo*, coal): having a *salic horizon* with a soil solution (1:1 in water) with a pH of ≥ 8.5 and $[HCO_3^-] > [SO_4^{2-}] > 2*[Cl^-]$ (*in Solonchaks only*).

Carbonic (cx) (from Latin *carbo*, coal): having a layer, ≥ 10 cm thick and starting ≤ 100 cm from the soil surface, with ≥ 5% organic carbon that belongs to *artefacts* (2).

Chernic (ch) (from Russian *chorniy*, black)**:** having a *chernic horizon* (2: Ano- and Panto- only).

Tonguichernic (tc) (from English *tongue*): having a *chernic horizon* that tongues into an underlying layer (2: Ano- and Panto- only; referring to the lower limit of the *chernic horizon*).

Chloridic (cl) (from Greek *chloros*, yellow-green): having a *salic horizon* with a soil solution (1:1 in water) with $[Cl^-] > 2*[SO_4^{2-}] > 2*[HCO_3^-]$ (*in Solonchaks only*).

Chromic (cr) (from Greek *chroma*, colour): having between 25 and 150 cm of the mineral soil surface a layer, ≥ 30 cm thick, that shows evidence of soil formation as defined in criterion 3 of the *cambic horizon* and that has, in ≥ 90% of its exposed area, a Munsell colour hue redder than 7.5YR and a chroma of > 4, both moist, and that does not meet the set of diagnostic criteria of the Rhodic qualifier.

Claric (cq) (from Latin *clarus*, bright): having between 25 and 100 cm of the mineral soil surface a layer, ≥ 30 cm thick, that consists of *claric material,* and the soil does not meet the set of diagnostic criteria of the Bathyspodic qualifier (*in Arenosols only*) (2: except Epi-).

Clayic (ce) (from English *clay*): consisting of *mineral material* and having, single or in combination, a texture class of clay, sandy clay or silty clay

- in one or more layers with a combined thickness of ≥ 30 cm, occurring within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting > 10 and < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Coarsic (cs) (from Englisch *coarse*): having < 20% (by volume, related to the whole soil) fine earth plus dead plant residues of any size, averaged over a depth of 75 cm from the soil surface or to a limiting layer starting > 25 cm from the soil surface, whichever is shallower.
Note: The volume occupied neither by fine earth nor by dead plant residues is occupied by coarse fragments, remnants of broken-up cemented layers > 2 mm, *artefacts* > 2 mm, or interstices.

Cohesic (co) (from Latin *cohaerere*, to stick together): having a *cohesic horizon* starting ≤ 150 cm from the mineral soil surface (2).

Columnic (cu) (from Latin *columna*, column): having a layer, ≥ 15 cm thick and starting ≤ 100 cm from the mineral soil surface, that has a columnar structure (2).

Cordic (cd): (from Latin *corda*, string): having two or more ribbon-like accumulations, ≥ 0.5 and < 2.5 cm thick, that are not cemented, have higher contents of Fe oxides and/or organic matter than the directly overlying and underlying layers, do not meet the set of diagnostic criteria of the Lamellic qualifier and have a combined thickness of ≥ 2.5 cm within 50 cm; the uppermost ribbon-like accumulation starting ≤ 200 cm from the mineral soil surface (2).

Cryic (cy) (from Greek *kryos*, cold, ice):
- having a *cryic horizon* starting ≤ 100 cm from the soil surface, or
- having a *cryic horizon* starting ≤ 200 cm from the soil surface with evidence of cryogenic alteration in some layer ≤ 100 cm from the soil surface

(1; Epi- and Endo- only; referring to the upper limit of the *cryic horizon*).

Cutanic (ct) (from Latin *cutis*, skin): having an *argic* or *natric horizon* that meets diagnostic criterion 2.b of the respective horizon.

Densic (dn) (from Latin *densus*, dense): having within 50 cm of the mineral soil surface a layer with a bulk density to the extent that roots cannot enter, except along cracks.

Differentic (df) (from Latin *differentia*, difference): having an *argic* or *natric horizon* that meets diagnostic criterion 2.a of the respective horizon.

Dolomitic (do) (from the mineral dolomite, named after the French geoscientist *Déodat de Dolomieu*): having *dolomitic material*
- in a layer, ≥ 30 cm thick and within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Dorsic (ds) (from Latin *dorsum*, at a lower position):
- in *Cryosols*, the *cryic horizon* starting > 100 cm from the soil surface,
- in *Ferralsols* and *Podzols*, the *ferralic*/*spodic horizon* starting > 100 cm from the mineral soil surface.

Drainic (dr) (from French *drainer*, to drain): having been artificially drained.

Duric (du) (from Latin *durus*, hard): having a *duric horizon* starting ≤ 100 cm from the mineral soil surface (2).

Hyperduric (ju) (from Greek *hyper*, over): having a *duric horizon* with ≥ 50% (by volume, related to the whole soil) durinodes or remnants of a broken-up *petroduric horizon* starting ≤ 100 cm from the mineral soil surface (2).

Dystric (dy) (from Greek *dys*, bad, and *trophae*, food):
- in *Histosols*, having a pH_{water} of < 5.5 in half or more of the part with *organic material*, within 100 cm of the soil surface,
- in other soils, having one or more layers consisting of *mineral material*,
  - between 20 and 100 cm of the mineral soil surface, or
  - between 20 cm of the mineral soil surface and a limiting layer starting > 25 cm from the mineral soil

surface,
whichever is shallower,
that have exchangeable Al > exchangeable (Ca+Mg+K+Na) in half or more of their combined thickness (3).

Hyperdystric (jd) (from Greek *hyper*, over):

- in *Histosols*, having a pH_{water} of < 5.5 throughout in the *organic material* within 100 cm of the soil surface and < 4.5 in the major part with *organic material* within 100 cm of the soil surface,
- in other soils, having *mineral material*, throughout
  - from 20 to 100 cm of the mineral soil surface, or
  - from 20 cm of the mineral soil surface to a limiting layer starting ≥ 50 cm from the mineral soil surface,

  whichever is shallower,
  that has exchangeable Al > exchangeable (Ca+Mg+K+Na); and in its major part exchangeable Al > 4 times the exchangeable (Ca+Mg+K+Na).

Orthodystric (od) (from Greek *orthos*, right):

- in *Histosols*, having a pH_{water} of < 5.5 throughout in the *organic material* within 100 cm of the soil surface,
- in other soils, having *mineral material*, throughout
  - from 20 to 100 cm of the mineral soil surface, or
  - from 20 cm of the mineral soil surface to a limiting layer starting ≥ 50 cm from the mineral soil surface,

  whichever is shallower,
  that has exchangeable Al > exchangeable (Ca+Mg+K+Na).

Note: Exchangeable cations are given in $cmol_c\ kg^{-1}$. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Ekranic (ek) (from French *écran*, shield): having *technic hard material* starting ≤ 5 cm from the soil surface (*in Technosols only*).

Endic (ed) (from Greek *endon*, inside):

- in *Cryosols*, the *cryic horizon* starting > 50 and ≤ 100 cm from the soil surface,
- in other soils, the uppermost respective diagnostic horizon of the RSG, not meeting the set of diagnostic criteria of the Petric qualifier, starting > 50 and ≤ 100 cm from the mineral soil surface.

Entic (et) (from Latin *recens*, young): not having an *albic horizon* above the *spodic horizon* (*in Podzols only*).

Epic (ep) (from Greek *epi*, over):

- in *Cryosols*, the *cryic horizon* starting ≤ 50 cm from the soil surface,
- in other soils, the uppermost respective diagnostic horizon of the RSG, not meeting the set of diagnostic criteria of the Petric qualifier, starting ≤ 50 cm from the mineral soil surface.

Escalic (ec) (from Spanish *escala*, terrace): soil has been truncated and/or locally transported to form human-made terraces.

Eutric (eu) (from Greek *eu*, good, and *trophae*, food):

- in *Histosols*, having a pH_{water} of ≥ 5.5 in the major part with *organic material*, within 100 cm of the soil surface,

- in other soils, having one or more layers consisting of *mineral material*,
  - ➢ between 20 and 100 cm of the mineral soil surface, or
  - ➢ between 20 cm of the mineral soil surface and a limiting layer starting > 25 cm from the mineral soil surface,

  whichever is shallower,
  that have exchangeable (Ca+Mg+K+Na) ≥ exchangeable Al in the major part of their combined thickness (3).

Hypereutric (je) (from Greek *hyper*, over):
- in *Histosols*, having a pH_{water} of ≥ 5.5 throughout in the *organic material* within 100 cm of the soil surface and ≥ 6.5 in the major part with *organic material* within 100 cm of the soil surface,
- in other soils, having *mineral material*, throughout
  - ➢ from 20 to 100 cm of the mineral soil surface, or
  - ➢ from 20 cm of the mineral soil surface to a limiting layer starting ≥ 50 cm from the mineral soil surface,

  whichever is shallower,
  that has exchangeable (Ca+Mg+K+Na) ≥ exchangeable Al; and in its major part exchangeable (Ca+Mg+K+Na) ≥ 4 times the exchangeable Al.

Oligoeutric (ol) (from Greek *oligos*, few): in soils other than *Histosols*, having one or more layers consisting of *mineral material*,
- ➢ between 20 and 100 cm of the mineral soil surface, or
- ➢ between 20 cm of the mineral soil surface and a limiting layer starting > 25 cm from the mineral soil surface,

whichever is shallower,
that have exchangeable (Ca+Mg+K+Na) ≥ exchangeable Al and exchangeable (Ca+Mg+K+Na) < 5 $cmol_c\ kg^{-1}$ clay in the major part of their combined thickness (3).

Orthoeutric (oe) (from Greek *orthos*, right):
- in *Histosols*, having a pH_{water} of ≥ 5.5 throughout in the *organic material* within 100 cm of the soil surface,
- in other soils, having *mineral material*, throughout
  - ➢ from 20 to 100 cm of the mineral soil surface, or
  - ➢ from 20 cm of the mineral soil surface to a limiting layer starting ≥ 50 cm from the mineral soil surface,

  whichever is shallower,
  that has exchangeable (Ca+Mg+K+Na) ≥ exchangeable Al.

Note: Exchangeable cations are given in $cmol_c\ kg^{-1}$. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).
Note: Oligoeutric has preference over Hypereutric and Orthoeutric.

Eutrosilic (es) (from Greek *eu*, good, and *trophae*, food, and Latin *silex*, silicon-containing material): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 30 cm with *andic properties* and a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) of ≥ 15 $cmol_c\ kg^{-1}$ fine earth (*in Andosols* only) (2).

Evapocrustic (ev) (from Latin *e*, out, and *vapor*, steam, and *crusta*, crust): having a saline crust, ≤ 2 cm thick, on the soil surface.

Ferralic (fl) (from Latin *ferrum*, iron, and *alumen*, alum): having a *ferralic horizon* starting ≤ 150 cm from the mineral soil surface (2).

Ferric (fr) (from Latin *ferrum*, iron): having a *ferric horizon* starting ≤ 100 cm from the mineral soil surface (2).

Manganiferric (mf) (from the chemical element *manganese*): having a *ferric horizon* starting ≤ 100 cm from the mineral soil surface in which ≥ 50% of the oximorphic features are black (2).

Ferritic (fe) (from Latin *ferrum*, iron): having a layer, ≥ 30 cm thick and starting ≤ 100 cm from the mineral soil surface, with ≥ 10% Fe_{dith} and not forming part of a *petroplinthic*, *pisoplinthic* or *plinthic horizon* (2).

Hyperferritic (jf) (from Greek *hyper*, over): having a layer, ≥ 30 cm thick and starting ≤ 100 cm from the mineral soil surface, with ≥ 30% Fe_{dith} and not forming part of a *petroplinthic*, *pisoplinthic* or *plinthic horizon* (2).

Fibric (fi) (from Latin *fibra*, fiber): having *organic material* that, after rubbing, consists of > two thirds (by volume, related to the fine earth plus all dead plant residues) of recognizable dead plant tissues in

- one or more layers with a combined thickness of ≥ 30 cm within 100 cm of the soil surface (2; no subqualifier if no *organic material* is present ≥ 60 cm of the soil surface), or
- the weighted average of the entire *organic material* within 100 cm of the soil surface

(*in Histosols only*).

Floatic (ft) (from English *to float*): having *organic material* floating on water (*in Histosols only*).

Fluvic (fv) (from Latin *fluvius*, river): having *fluvic material*, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface (2).

Akrofluvic (kf) (from Greek *akra*, top): having *fluvic material* from the mineral soil surface to a depth of ≥ 5 cm, but < 25 cm thick. (In addition to the Akrofluvic subqualifier, a soil may also have the Amphifluvic, the Katofluvic or the Endofluvic subqualifier.)

Orthofluvic (of) (from Greek *orthos*, right): having *fluvic material*:

- from the mineral soil surface to a depth of ≥ 5 cm, *and*
- ≥ 25 cm thick and starting ≤ 25 cm from the mineral soil surface.

Folic (fo) (from Latin *folium*, leaf): having a *folic horizon* starting at the soil surface.

Skeletofolic (ko) (from Greek *skeletos*, dried out): having a *folic horizon* with ≥ 40% (by volume, weighted average, related to the whole soil) coarse fragments.

Fractic (fc) (from Latin *fractus*, broken): having a layer, ≥ 10 cm thick and starting ≤ 100 cm from the mineral soil surface, consisting of a broken-up *petrocalcic* or *petrogypsic horizon*, the remnants of which:

- occupy ≥ 40% (by volume, related to the whole soil), *and*
- have an average horizontal length of < 10 cm and/or occupy < 80% (by volume, related to the whole soil) (2).

Calcifractic (cf) (from Latin *calx*, lime): having a layer, ≥ 10 cm thick and starting ≤ 100 cm from the mineral soil surface, consisting of a broken-up *petrocalcic horizon*, the remnants of which:

- occupy ≥ 40% (by volume, related to the whole soil), *and*
- have an average horizontal length of < 10 cm and/or occupy < 80% (by volume, related to the whole soil) (2).

Gypsofractic (gf) (from Greek *gypsos*, gypsum): having a layer, ≥ 10 cm thick and starting ≤ 100 cm from the mineral soil surface, consisting of a broken-up *petrogypsic horizon*, the remnants of which:

- occupy ≥ 40% (by volume, related to the whole soil), *and*

- have an average horizontal length of < 10 cm and/or occupy < 80% (by volume, related to the whole soil) (2).

Fragic (fg) (from Latin *fragilis*, fragile): having a *fragic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Garbic (ga) (from English *garbage*): having a layer, ≥ 20 cm thick and within 100 cm of the soil surface, with ≥ 20% (by volume, weighted average, related to the whole soil) *artefacts*, ≥ 35% (by volume, related to the whole soil) of which contain ≥ 20% organic carbon (e.g. organic waste) (*in Technosols only*) (2).

Hypergarbic (jb) (from Greek *hyper*, over): having a layer, ≥ 50 cm thick and within 100 cm of the soil surface, consisting of *organotechnic material* (*in Technosols only*) (2).

Gelic (ge) (from Latin *gelare*, to freeze):

- having a layer with a soil temperature of < 0 °C for ≥ 2 consecutive years, starting ≤ 200 cm from the soil surface, *and*
- not having a *cryic horizon* starting ≤ 100 cm from the soil surface, *and*
- not having a *cryic horizon* starting ≤ 200 cm from the soil surface with evidence of cryogenic alteration in some layer within 100 cm of the soil surface.

Gelistagnic (gt) (from Latin *gelare*, to freeze, and *stagnare*, to flood): having temporary water saturation caused by a frozen layer.

Geoabruptic (go): *see Abruptic.*

Geric (gr) (from Greek *geraios*, old): having within 100 cm of the mineral soil surface a layer that has a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) of < 6 $cmol_c$ kg^{-1} clay (2).

Hypergeric (jq) (from Greek *hyper*, over): having within 100 cm of the mineral soil surface a layer that has a sum of exchangeable bases (by 1 *M* NH_4OAc, pH 7) plus exchangeable Al (by 1 *M* KCl, unbuffered) of < 1.5 $cmol_c$ kg^{-1} clay (2).

Gibbsic (gi) (from the mineral gibbsite, named after the US mineralogist *George Gibbs*): having a layer, ≥ 30 cm thick and starting ≤ 100 cm from the mineral soil surface, containing ≥ 25% gibbsite in the clay fraction (2).

Gilgaic (gg) (from Aboriginal Australian *gilgai*, water hole): having at the soil surface microhighs and microlows with a difference in level of ≥ 10 cm, i.e. gilgai microrelief (*in Vertisols only*).

Glacic (gc) (from Latin *glacies*, ice): having a layer, ≥ 30 cm thick and starting ≤ 100 cm from the soil surface, containing ≥ 75% ice (by volume, related to the whole soil) (2).

Gleyic (gl) (from Russian folk name *gley*, wet bluish clay): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that has *gleyic properties* throughout and *reducing conditions* in some parts of every sublayer (2).

Inclinigleyic (iy) (from Latin *inclinare*, to bow): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil, that has *gleyic properties* throughout and *reducing conditions* in some parts of every sublayer; and having a slope inclination of ≥ 5% and a subsurface water flow for some time during the year (2).

Protogleyic (qy) (from Greek *proton*, first): having a layer, ≥ 10 cm thick and starting ≤ 75 cm from the mineral soil surface, that has *gleyic properties* throughout and *reducing conditions* in some parts of every sublayer (2).

Relictigleyic (rl) (from Latin *relictus*, left back): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that meets criterion 2 of the *gleyic properties* throughout and not having *reducing conditions* (2).

Glossic (gs) (from Greek *glossa*, tongue)**:** having *albeluvic glossae* starting ≤ 100 cm from the mineral soil surface.

Greyzemic (gz) (from English *grey*, and Russian *zemlya*, earth): having uncoated sand and/or coarse silt grains on soil aggregate surfaces in the lower half of a *mollic horizon*.

Grumic (gm) (from Latin *grumus*, soil heap): having at the mineral soil surface a layer, ≥ 1 cm thick, with strong granular structure or strong angular or subangular blocky structure with an aggregate size of ≤ 1 cm, i.e. 'self-mulching' (*in Vertisols only*).

Gypsic (gy) (from Greek *gypsos*, gypsum): having a *gypsic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Hypergypsic (jg) (from Greek *hyper*, over): having a *gypsic horizon* with a gypsum content of ≥ 50% and starting ≤ 100 cm from the mineral soil surface (2).

Protogypsic (qq) (from Greek *proton*, first): having a layer with *protogypsic properties* starting ≤ 100 cm from the mineral soil surface and not having a *gypsic* or *petrogypsic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Gypsiric (gp) (from Greek *gypsos*, gypsum): having *gypsiric material*

- in a layer, ≥ 30 cm thick and within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting < 60 cm from the mineral soil surface;

and not having a *gypsic* or *petrogypsic horizon* starting ≤ 100 cm from the mineral soil surface (2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Haplic (ha) (from Greek *haplous*, simple): no other principal qualifier of the respective RSG applies.

Hemic (hm) (from Greek *hemisys*, half): having *organic material* that, after rubbing, consists of ≤ two thirds and > one sixth (by volume, related to the fine earth plus all dead plant residues) of recognizable dead plant tissues in

- one or more layers with a combined thickness of ≥ 30 cm within 100 cm of the soil surface (2; no subqualifier if no *organic material* is present ≥ 60 cm of the soil surface), or
- the weighted average of the entire *organic material* within 100 cm of the soil surface

(*in Histosols only*).

Histic (hi) (from Greek *histos*, tissue): having a *histic horizon* starting

- at the soil surface, *or*
- directly below a layer, < 40 cm thick, consisting of *mulmic material*, *or*
- directly below a layer, < 40 cm thick, consisting of *organic material*, that is saturated with water for < 30 consecutive days in most years and is not drained.

Skeletohistic (kh) (from Greek *skeletos*, dried out): having a *histic horizon* starting

- at the soil surface or
- directly below a layer, < 40 cm thick, consisting of *mulmic material* or
- directly below a layer, < 40 cm thick, consisting of *organic material* that is saturated with water for < 30 consecutive days in most years and is not drained;

with ≥ 40% (by volume, weighted average, related to the whole soil) coarse fragments.

Hortic (ht) (from Latin *hortus*, garden): having a *hortic horizon* (2: Panto- only).

Humic (hu) (from Latin *humus*, earth): having ≥ 1% *soil organic carbon* as a weighted average to a depth of 50 cm from the mineral soil surface (if a limiting layer starts within the specified depth, the depth range below that contributes a 0 to the calculation of the weighted average).

Hyperhumic (jh) (from Greek *hyper*, over): having ≥ 5% *soil organic carbon* as a weighted average to a depth of 50 cm from the mineral soil surface.

Profundihumic (dh) (from Latin *profundus*, deep): having to a depth of 100 cm from the mineral soil surface ≥ 1.4% *soil organic carbon* as a weighted average and ≥ 1% *soil organic carbon* throughout.

Hydragric (hg) (from Greek *hydor*, water, and Latin *ager*, field): having an *anthraquic horizon* and a directly underlying *hydragric horizon*, the latter starting ≤ 100 cm from the soil surface.

Hyperhydragric (jy) (from Greek *hyper*, over): having an *anthraquic horizon* and a directly underlying *hydragric horizon* with a combined thickness of ≥ 100 cm.

Hydric (hy) (from Greek *hydor*, water): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 35 cm that have *andic properties* and a water content ≥ 70% (mass of water divided by mass of dry soil) at 1500 kPa tension, measured without previous drying of the sample (*in Andosols only*) (2).

Hydrophobic (hf) (from Greek *hydor*, water, and *phobos*, fear): water-repellent, i.e. water stands on a dry soil surface for ≥ 60 seconds (*in Arenosols only*).

Hyperalic (jl) (from Greek *hyper*, over, and Latin *alumen*, alum): having an *argic horizon*, starting ≤ 100 cm from the mineral soil surface, that has a silt to clay ratio of < 0.6 and an Al saturation (effective) of ≥ 50%, throughout or to a depth of 50 cm below its upper limit, whichever is thinner (*in Alisols only*).

Hyperartefactic (ja) (from Greek *hyper*, over, and Latin *ars*, art, and *factus*, made): having ≥ 50% (by volume, weighted average, related to the whole soil) *artefacts* within 100 cm of the soil surface or to a limiting layer, whichever is shallower (*in Technosols only*).

Hypercalcic (jc): *see Calcic.*

Hypereutric (je): *see Eutric.*

Hypergypsic (jy): *see Gypsic.*

Hypernatric (jn): *see Natric.*

Hyperorganic (jo) (from Greek *hyper*, over, and *organon*, tool): having *organic material* ≥ 200 cm thick (*in Histosols only*).

Hypersalic (jz): *see Salic.*

Hyperspodic (jp): *see Spodic*.

Immissic (im) (from Latin *immissus*, sent inside): having at the soil surface a layer, ≥ 10 cm thick, with ≥ 20% (by volume) sedimented dust, soot or ash that meets the diagnostic criteria of *artefacts* (2: Ano- and Panto- only).

Inclinic (ic) (from Latin *inclinare*, to bow): having

- a slope inclination of ≥ 5%, *and*
- a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, with *gleyic* or *stagnic properties* and a subsurface water flow for some time during the year.

Infraandic (ia) (from Latin *infra*, below, and Japanese *an*, dark, and *do*, soil): having a layer, ≥ 15 cm thick, that underlies a soil classified with preference according to the 'Rules for naming soils' (Chapter 2.4) and that meets diagnostic criteria 2 and 3 of the *andic properties* and fails diagnostic criterion 1.

Infraspodic (is) (from Latin *infra*, below, and Greek *spodos*, wood ash): having a layer that underlies a soil classified with preference according to the 'Rules for naming soils' (Chapter 2.4) and that meets diagnostic criteria 3 to 7 of the *spodic horizon* and fails diagnostic criterion 1 or 2 or both.

Irragric (ir) (from Latin *irrigare*, to irrigate, and *ager*, field): having an *irragric horizon* (2: Panto- only).

Isolatic (il) (from Italian *isola*, island): having, above *technic hard material*, above a geomembrane or above a continuous layer of *artefacts* starting ≤ 100 cm from the soil surface, soil material containing fine earth without any contact to other soil material containing fine earth (e.g. soils on roofs or in pots).

Isopteric (ip) (related to *Isoptera*, zoologic order of termites): having a layer, ≥ 30 cm thick and starting at the mineral soil surface, that is remodelled by termites, has a bulk density ≤ 1.3 kg dm^{-3} and < 5% particles ≥ 630 µm (2: Ano- and Panto- only).

Kalaic (ka) (from Tamil *kalai*, art): having a layer, ≥ 10 cm thick and starting ≤ 90 cm from the soil surface, with ≥ 50% (by volume, weighted average, related to the whole soil) *artefacts* (2: Epi-, Endo- and Amphi- only).

Protokalaic (qk) (from Greek *proton*, first): having a layer, ≥ 10 cm thick and starting ≤ 90 cm from the soil surface, with ≥ 25% (by volume, weighted average, related to the whole soil) *artefacts* (2: Epi-, Endo- and Amphi- only).

Lamellic (ll): (from Latin *lamella*, metal blade): having two or more lamellae, ≥ 0.5 and < 7.5 cm thick, that have one or both of the following:

- higher clay contents than the directly overlying and underlying layers as stated in the diagnostic criteria 2.a of the *argic horizon*, *or*
- meet the diagnostic criteria 2.b of the *argic horizon*,

with or without other accumulations, and that have a combined thickness of ≥ 5 cm within 50 cm; the uppermost lamella starting ≤ 100 cm from the mineral soil surface (2).

Totilamellic (ta) (from Latin *totus*, complete): having an *argic horizon* that consists entirely of lamellae starting ≤ 100 cm from the mineral soil surface.

Lapiadic (ld) (from Latin *lapis*, stone): having at the soil surface *continuous rock* that has dissolution features (rills, grooves), ≥ 20 cm deep and covering ≥ 10 and < 50% of the surface of the *continuous rock* (*in Leptosols only*).

Laxic (la) (from Latin *laxus*, slack): having between 25 and 75 cm from the mineral soil surface a mineral soil layer, ≥ 20 cm thick, that has a bulk density of ≤ 0.9 kg dm^{-3}.
Note: For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined at 105 °C (see Annex 2, Chapter 9.5).

Leptic (le) (from Greek *leptos*, thin): having *continuous rock* starting ≤ 100 cm from the soil surface (1: Epi- and Endo- only).

Lignic (lg) (from Latin *lignum*, wood): having inclusions of intact wood fragments that make up ≥ 25% of the soil volume (related to the fine earth plus all dead plant residues), within 50 cm from the soil surface.

Limnic (lm) (from Greek *limnae*, pool): having one or more layers with *limnic material* with a combined thickness of ≥ 10 cm within 100 cm of the soil surface (2).
Minerolimnic (ml) (from Celtic *mine*, mineral): having one or more layers with *limnic material* consisting of *mineral material* with a combined thickness of ≥ 10 cm within 100 cm of the soil surface (2).
Organolimnic (oo) (from Greek *organon*, tool): having one or more layers with *limnic material* consisting of *organic material* with a combined thickness of ≥ 10 cm within 100 cm of the soil surface (2).

Limonic (ln) (from Greek *leimon*, meadow): having a *limonic horizon*, starting ≤ 100 cm from the soil surface (2).

Linic (lc) (from Latin *linea*, line): having a continuous, very slowly permeable to impermeable constructed geomembrane of any thickness starting ≤ 100 cm from the soil surface (1).

Lithic (li) (from Greek *lithos*, stone): having *continuous rock* starting ≤ 10 cm from the soil surface (*in Leptosols only*).
Nudilithic (nt) (from Latin *nudus*, naked): having *continuous rock* at the soil surface (*in Leptosols only*).

Litholinic (lh) (from Greek *lithos*, stone, and Latin *linea*, line): having a layer, ≥ 2 and ≤ 20 cm thick and starting ≤ 150 cm from the mineral soil surface, that has ≥ 40% (by volume, related to the whole soil) coarse fragments and in the layers above and below < 10% (by volume, related to the whole soil) coarse fragments (*stone line*) (1, referring to the upper limit of the layer).

Lixic (lx) (from Latin *lixivia*, washed-out substances): having an *argic horizon* starting ≤ 100 cm from the mineral soil surface with a CEC (by 1 *M* NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay in some subhorizon within 150 cm of the mineral soil surface; and having exchangeable Al ≤ exchangeable (Ca+Mg+K+Na) in half or more of the depth range between 50 and 100 cm of the mineral soil surface or the lower half of the mineral soil above a limiting layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).
Note: Exchangeable cations are given in $cmol_c$ kg^{-1}. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Loamic (lo) (from English *loam*): consisting of *mineral material* and having, single or in cobmination, a texture class of loam, sandy loam, clay loam, sandy clay loam or silty clay loam

- in one or more layers with a combined thickness of ≥ 30 cm, occurring within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting > 10 and < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Luvic (lv) (from Latin *eluere*, to wash): having an *argic horizon* starting ≤ 100 cm from the mineral soil surface with a CEC (by 1 *M* NH_4OAc, pH 7) of ≥ 24 $cmol_c$ kg^{-1} clay throughout within 150 cm of the mineral soil surface; and having exchangeable Al ≤ exchangeable (Ca+Mg+K+Na) in half or more of the depth range between 50 and 100 cm of the mineral soil surface or the lower half of the mineral soil above a limiting layer starting ≤ 100 cm from the mineral soil surface, whichever is shallower (2).
Note: Exchangeable cations are given in $cmol_c$ kg^{-1}. If these data are not available, pH values may be used according to Annex 2 (Chapter 9.13).

Magnesic (mg) (from the chemical element *magnesium*): having an exchangeable Ca to Mg ratio of < 1

- in a layer, ≥ 30 cm thick and within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Hypermagnesic (jm) (from Greek *hyper*, over): having an exchangeable Ca to Mg ratio of < 0.1

- in a layer, ≥ 30 cm thick and within 100 cm of the mineral soil surface, *or*
- in the major part between the mineral soil surface and a limiting layer starting < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Mahic (ma) (from Maori *mahi*, work):

- having a layer, ≥ 10 cm thick and starting ≤ 50 cm from the soil surface, with ≥ 80% (by volume, weighted average, related to the whole soil) *artefacts*; *and*
- having < 20% (by volume, weighted average, related to the whole soil) *artefacts* in the upper 100 cm from the soil surface or to a limiting layer, whichever is shallower.

Mawic (mw): (from Kiswahili *mawe*, stones): having a layer of coarse fragments that, together with overlying *organic material*, if present, starts at the soil surface and has a thickness of

- ≥ 10 cm if overlying *continuous rock* or *technic hard material*; *or*
- ≥ 40 cm;

and the major part of the interstices between the coarse fragments is filled with *organic material* and the remaining interstices, if present, are void (*in Histosols only*) (1: Epi- and Endo- only; referring to the upper limit of the layer of coarse fragments).

Mazic (mz) (from Spanish *maza*, cudgel): having a massive structure and a rupture-resistance class of at least hard in the upper 20 cm of the mineral soil (*in Vertisols only*).

Mineralic (mi) (from Celtic *mine*, mineral): having, within 100 cm of the soil surface, one or more layers of *mineral material*, not consisting of *mulmic material*, with a combined thickness of ≥ 20 cm, above or in between layers of *organic material* (*in Histosols only*) (2: Epi-, Endo-, Amphi- and Poly- only).

Akromineralic (km) (from Greek *akra*, top): having *mineral material*, ≥ 10 cm thick, not consisting of *mulmic material* and starting at the soil surface, but the layers of *mineral material*, not consisting of *mulmic material*, above or in between layers of *organic material* have a combined thickness of < 20 cm (*in Histosols only*).

Orthomineralic (oi) (from Greek *orthos*, right): having:

- *mineral material*, ≥ 10 cm thick, not consisting of *mulmic material* and starting at the soil surface, *and*
- within 100 cm of the soil surface, one or more layers of *mineral material*, not consisting of *mulmic material*, with a combined thickness of ≥ 20 cm, above or in between layers of *organic material*

(*in Histosols only*) (2: Epi-, Endo-, Amphi- and Poly- only).

Mochipic (mc) (from Nahuatl *mochipa*, always): having a layer with *stagnic properties*, ≥ 25 cm thick and within 100 cm of the mineral soil surface, that is water-saturated for ≥ 300 cumulative days in most years.

Mollic (mo) (from Latin *mollis*, soft): having a *mollic horizon* (2: Ano- and Panto- only).

Anthromollic (am) (from Greek *anthropos*, human being): having a *mollic horizon* and *anthric properties* (2: Ano- and Panto- only).

Somerimollic (sm) (from Spanish *somero*, superficial): having a *mollic horizon*, < 20 cm thick.

Tonguimollic (tm) (from English *tongue*): having a *mollic horizon* that tongues into an underlying layer (2: Ano- and Panto- only; referring to the *mollic horizon*, not to the tongues).

Mulmic (mm) (from German *Mulm*, powdery detritus): having a layer, ≥ 10 cm thick, consisting of *mulmic material* and starting at the mineral soil surface.

Murshic (mh) (from Polish *mursz*, decay): having a drained *histic horizon*, ≥ 20 cm thick, and starting

- at the soil surface, *or*
- directly below a layer, < 40 cm thick, consisting of *mulmic material*, *or*
- directly below a layer, < 40 cm thick, consisting of *organic material* that is saturated with water for < 30 consecutive days in most years and is not drained,

and having a bulk density of ≥ 0.2 kg dm^{-3} and one or both of the following:

- moderate to strong granular structure or moderate to strong angular or subangular blocky structure, *or*
- cracks

(*in Histosols only*) (2).

Note: For bulk density, the volume is determined after an undried soil sample has been desorbed at 33 kPa (no prior drying), and afterwards the weight is determined at 105 °C (see Annex 2, Chapter 9.5).

Muusic (mu): (from Sakha *muus*, ice): having *organic material* starting at the soil surface that directly overlies ice (*in Histosols only*) (1: Epi- and Endo- only; referring to the upper limit of the ice).

Naramic (nr) (from Hindi, *naram*, soft):

- in *Gypsisols*: having a *gypsic horizon* above a *petrogypsic horizon* that starts ≤ 100 cm from the mineral soil surface (2).
- in *Calcisols*: having a *calcic horizon* above a *petrocalcic horizon* that starts ≤ 100 cm from the mineral soil surface (2).

Natric (na) (from Arabic *natroon*, salt): having a *natric horizon* starting ≤ 100 cm from the mineral soil surface (2).

Hypernatric (jn) (from Greek *hyper*, over): having a *natric horizon* with an exchangeable Na percentage (ESP) of ≥ 15 throughout the entire *natric horizon* or within its upper 40 cm, whichever is thinner.

Nudinatric (nn) (from Latin *nudus*, naked): having a *natric horizon* starting at the mineral soil surface.

Nechic (ne) (from Amharic *nech*, white): having a pH_{water} of < 5 and uncoated mineral grains of sand and/or coarse silt size in a darker matrix somewhere within 5 cm of the mineral soil surface and no *spodic horizon* starting ≤ 200 cm from the mineral soil surface.

Neobrunic (nb): *see Brunic*

Neocambic (nc): *see Cambic*.

Nitic (ni) (from Latin *nitidus*, shiny): having a *nitic horizon* starting ≤ 100 cm from the mineral soil surface. (2)

Novic (nv) (from Latin *novus*, new): having a layer, ≥ 5 and < 50 cm thick, overlying a buried soil that is classified with preference according to the 'Rules for naming soils' (Chapter 2.4).

Areninovic (aj) (from Latin *arena*, sand): having a layer, ≥ 5 and < 50 cm thick, that has, single or in combination, a texture class of sand or loamy sand in its major part, overlying a buried soil that is classified with preference according to the 'Rules for naming soils' (Chapter 2.4).

Clayinovic (cj) (from English *clay*): having a layer, ≥ 5 and < 50 cm thick, that has, single or in combination, a texture class of clay, sandy clay or silty clay in its major part, overlying a buried soil that is classified with preference according to the 'Rules for naming soils' (Chapter 2.4).

Loaminovic (lj) (from English *loam*): having a layer, ≥ 5 and < 50 cm thick, that has, single or in combination, a texture class of loam, sandy loam, clay loam, sandy clay loam or silty clay loam in its major part, overlying a buried soil that is classified with preference according to the 'Rules for naming soils' (Chapter 2.4).

Siltinovic (sj) (from English *silt*): having a layer, ≥ 5 and < 50 cm thick, that has, single or in combination, a texture class of silt or silt loam in its major part, overlying a buried soil that is classified with preference according to the 'Rules for naming soils' (Chapter 2.4).

Combinations possible to indicate the deposited material (see Chapter 2.4).

Nudiargic (ng) (from Latin *nudus*, naked, and *argilla*, white clay)**:** having an *argic horizon* starting at the mineral soil surface.

Nudilithic (nt): *see Lithic.*

Nudinatric (nn): *see Natric.*

Ochric (oh): (from Greek *ochros*, pale): having ≥ 0.2% *soil organic carbon* (weighted average) in the upper 10 cm of the mineral soil; and not having a *mollic* or *umbric horizon* and not meeting the set of diagnostic criteria of the Humic qualifier.

Ombric (om) (from Greek *ombros*, rain): having a *histic horizon*, the upper ≥ 20 cm or at least the upper half of which, whichever is shallower, are saturated predominantly with rainwater (*in Histosols only*).

Ornithic (oc) (from Greek *ornis*, bird): having a layer, ≥ 15 cm thick, with *ornithogenic material* starting

≤ 50 cm from the soil surface (2).

Orthofluvic (of): *see Fluvic*.

Ortsteinic (os) (from Old Saxonian *arut*, hard): having a *spodic horizon* that has a subhorizon that is cemented ('ortstein') with a cementation class of at least moderately cemented in ≥ 50% of its horizontal extension and that does not meet the set of diagnostic criteria of the Placic qualifier (*in Podzols only*).

Oxyaquic (oa) (from Greek *oxys*, sour, and Latin *aqua*, water): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that is saturated with water during a period of ≥ 20 consecutive days; and not having *gleyic properties* and not having *stagnic properties* in any layer within 100 cm of the mineral soil surface (2).

Oxygleyic (oy) (from Greek *oxys*, sour, and Russian folk name *gley*, wet bluish clay): not having, within 100 cm of the mineral soil surface, a layer that meets diagnostic criterion 1 of the *gleyic properties* (*in Gleysols only*).

Pachic (ph) (from Greek *pachys*, thick): having a *chernic*, *mollic* or *umbric horizon* ≥ 50 cm thick (*in Chernozems, Kastanozems, Phaeozems and Umbrisols only*).

Panpaic (pb) (from Quechua *p'anpay*, to bury): having a *panpaic horizon* starting ≤ 100 cm from the mineral soil surface (1, referring to the upper limit of the *panpaic horizon*).

Pellic (pe) (from Greek *pellos*, dusty): having in the upper 30 cm of the mineral soil a Munsell colour value of ≤ 3 and a chroma of ≤ 2, both moist (*in Vertisols only*).

Pelocrustic (p) (from Greek *pelos*, clay, and Latin *crusta*, crust): having a permanent physical surface crust with ≥ 30% clay (*in Vertisols only*).

Petric (pt) (from Greek *petros*, rock): having the cemented diagnostic horizon of the respective RSG, starting ≤ 100 cm from the mineral soil surface (1: Epi- and Endo- only).

Nudipetric (np) (from Latin *nudus*, naked): having the cemented diagnostic horizon of the respective RSG, starting at the mineral soil surface.

Petrocalcic (pc) (from Greek *petros*, rock, and Latin *calx*, lime): having a *petrocalcic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Petroduric (pd) (from Greek *petros*, rock, and Latin *durus*, hard): having a *petroduric horizon* starting ≤ 100 cm from the mineral soil surface (2).

Petrogypsic (pg) (from Greek *petros*, rock, and *gypsos*, gypsum): having a *petrogypsic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Petroplinthic (pp) (from Greek *petros*, rock, and *plinthos*, brick): having a *petroplinthic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Petrosalic (ps) (from Greek *petros*, rock, and Latin *sal*, salt): having a layer, ≥ 10 cm thick and within 100 cm of the mineral soil surface, which is cemented by salts more soluble than gypsum (2).

Pisoplinthic (px) (from Latin *pisum*, pea, and Greek *plinthos*, brick): having a *pisoplinthic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Placic (pi) (from Greek *plax*, flat stone): having a layer, ≥ 0.1 and < 2.5 cm thick and within 100 cm of the mineral soil surface, that is cemented, with a cementation class of at least weakly cemented, by Fe oxides, with or without other cementing agents, and is continuous to the extent that vertical fractures, if present, have an average horizontal spacing of ≥ 10 cm and occupy < 20% (by volume, related to the whole soil) (2: Epi-, Endo- and Amphi- only).

Plaggic (pa) (from Low German *plaggen*, sod): having a *plaggic horizon* (2: Panto- only).

Plinthic (pl) (from Greek *plinthos*, brick): having a *plinthic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Posic (po) (from Latin *positivus*, given): having layer, ≥ 30 cm thick and starting ≤ 100 cm from the mineral soil surface, that has a zero or positive charge (pH_{KCl} - $pH_{water} \geq 0$, both in 1:1 solution) (2).

Pretic (pk) (from Portuguese *preto*, black): having a *pretic horizon* (2: Panto- only).

Profondic (pn) (from French *profond*, deep): having an *argic horizon*, in which the clay content does not decrease by ≥ 20% (relative) from its maximum within 150 cm of the mineral soil surface, throughout.

Protic (pr) (from Greek *proton*, first): showing no soil horizon development, with the exception of a *cryic horizon*, which may be present.

Protoandic (qa): *see Andic*.

Protoargic (qg) (from Greek *proton*, first, and Latin *argilla*, white clay): having an absolute clay increase of ≥ 4% from one layer to the directly underlying layer, within 100 cm of the mineral soil surface (*in Arenosols only*) (2).

Protocalcic (qc): *see Calcic*.

Protospodic (qp): *see Spodic*.

Protovertic (qv): *see Vertic*.

Puffic (pu) (from English *to puff*): having a chemical surface crust formed by readily soluble salts.

Pyric (py) (from Greek *pyr*, fire): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 10 cm with ≥ 5% (by exposed area, related to the fine earth plus black carbon of any size) visible black carbon and not forming part of a *pretic horizon* (2).

Raptic (rp) (from Latin *raptus*, broken): having a *lithic discontinuity* at some depth ≤ 100 cm from the mineral soil surface, that is not related to *aeolic*, *fluvic, solimovic* or *tephric material* (1).

Reductaquic (ra) (from Latin *reductus*, drawn back, and *aqua*, water): having above a *cryic horizon* a layer,

≥ 25 cm thick and starting ≤ 75 cm from the soil surface, that is saturated with water during the thawing period and that has at some time of the year *reducing conditions* (*in Cryosols only*) (2).

Reductic (rd) (from Latin *reductus*, drawn back): having *reducing conditions* in ≥ 25% (by volume) within 100 cm of the soil surface, caused by gaseous emissions, e.g. methane or carbon dioxide, or caused by liquid intrusions other than water, e.g. gasoline.

Reductigleyic (ry) (Latin *reductus*, drawn back, and Russian folk name *gley*, wet bluish clay): not having, ≥ 40 cm from the mineral soil surface, a layer that meets diagnostic criterion 2 of the *gleyic properties* (*in Gleysols only*).

Relocatic (rc) (from Latin *re*, again, and *locatus*, put): being remodelled in situ or within the immediate vicinity by human activity to a depth of ≥ 100 cm (e.g. by deep ploughing, refilling soil pits or levelling land) and no formation of diagnostic horizons after remodelling, throughout, except a *mollic* or *umbric horizon* (in *Technosols*, Relocatic is redundant, except in combination with the Ekranic, Thyric or Linic qualifier); a destroyed diagnostic horizon (excluding the horizons that are defined as surface horizon according to their diagnostic criteria) may be added with a hyphen, e.g. Spodi-Relocatic, Spodi-Epirelocatic, however, there are no codes provided for these additions (4: Epi- only).

Rendzic (rz) (from Polish *rzendzic*, to grate in contact with a plough blade): having a *mollic horizon* that contains or directly overlies *calcaric material* containing ≥ 40% calcium carbonate equivalent or that directly overlies calcareous rock containing ≥ 40% calcium carbonate equivalent (2: Ano- and Panto- only).

Somerirendzic (sr) (from Spanish *somero*, superficial): having a *mollic horizon*, < 20 cm thick, that directly overlies calcareous rock containing ≥ 40% calcium carbonate equivalent.

Retic (rt) (from Latin *rete*, net): having *retic properties* starting ≤ 100 cm from the mineral soil surface.

Rheic (rh) (from Greek *rhein*, to flow): having a *histic horizon*, in which groundwater or flowing water ascends to < 20 cm of the soil surface or reaches the *histic horizon*'s upper half, whichever is shallower (*in Histosols only*).

Rhodic (ro): (from Greek *rhodon*, rose): having between 25 and 150 cm of the mineral soil surface a layer, ≥ 30 cm thick, that shows evidence of soil formation as defined in criterion 3 of the *cambic horizon* and that has, in ≥ 90% of its exposed area, a Munsell colour hue redder than 5YR moist, a value of < 4 moist, and a value dry, not more than one unit higher than the moist value.

Rockic (rk): (from English *rock*): having *organic material* starting at the soil surface that directly overlies *continuous rock* or *technic hard material* (*in Histosols only*) (1: Epi- and Endo- only; referring to the upper limit of the *continuous rock* or *technic hard material*).

Rubic (ru): (from Latin *ruber*, red): having between 25 and 100 cm of the mineral soil surface a layer, ≥ 30 cm thick, that does not consist of *claric material* and that has, in ≥ 90% of its exposed area, a Munsell colour hue redder than 10YR and/or a chroma of ≥ 5, both moist (*in Arenosols only*) (2: except Epi-).

Rustic (rs) (from English *rust*): having a *spodic horizon* that has a Munsell colour chroma of ≥ 6, moist, throughout ('Iron Podzols'; *in Podzols only*).

Salic (sz) (from Latin *sal*, salt): having a *salic horizon* starting ≤ 100 cm from the soil surface (2).

Hypersalic (jz) (from Greek *hyper*, over): having a *salic horizon* with a subhorizon, ≥ 15 cm thick and starting ≤ 100 cm from the soil surface, that has an EC_e of ≥ 30 dS m^{-1} at 25 °C (2).

Protosalic (qz) (from Greek *proton*, first): having within 100 cm of the soil surface a layer that has an EC_e of ≥ 4 dS m^{-1} at 25 °C; and not having a *salic horizon* starting ≤ 100 cm from the soil surface (2).

Sapric (sa) (from Greek *sapros*, rotten): having *organic material* that, after rubbing, consists of ≤ one sixth (by volume, related to the fine earth plus all dead plant residues) of recognizable dead plant tissues in

- one or more layers with a combined thickness of ≥ 30 cm within 100 cm of the soil surface (2; no subqualifier if no *organic material* is present ≥ 60 cm of the soil surface), or
- the weighted average of the entire *organic material* within 100 cm of the soil surface

(*in Histosols only*).

Saprolithic (sh) (from Greek *sapros*, rotten, and *lithos*, stone): having a layer, ≥ 30 cm thick and starting ≤ 150 cm from the mineral soil surface, that has rock structure in ≥ 75% (by volume, related to the whole soil) and a CEC (by 1 M NH_4OAc, pH 7) of < 24 $cmol_c$ kg^{-1} clay (2).

Sideralic (se) (from Greek *sideros*, iron, and *Latin* alumen, alum): having within 150 cm of the mineral soil surface a layer that has *sideralic properties*; and not having a *ferralic horizon* starting ≤ 150 cm from the mineral soil surface (2).

Hypersideralic (jr) (from Greek *hyper*, over): having within 150 cm of the mineral soil surface a layer that has ≥ 8% clay, has a CEC (by 1 *M* NH_4OAc, pH 7) of < 16 $cmol_c$ kg^{-1} clay and shows evidence of soil formation as defined in criterion 3 of the *cambic horizon*; and not having a *ferralic horizon* starting ≤ 150 cm from the mineral soil surface (2).

Silandic (sn) (from Latin *silex*, silicon-containing material, and Japanese *an*, dark, and *do*, soil): having within 100 cm of the soil surface one or more layers with a combined thickness of ≥ 15 cm with *andic properties* and a Si_{ox} content of ≥ 0.6% (*in Andosols only*) (2).

Siltic (sl) (from English *silt*): consisting of *mineral material* and having, single or in combination, a texture class of silt or silt loam

- in one or more layers with a combined thickness of ≥ 30 cm, occurring within 100 cm of the mineral soil surface, or
- in the major part between the mineral soil surface and a limiting layer starting > 10 and < 60 cm from the mineral soil surface

(2; no subqualifier if a limiting layer starts < 60 cm from the mineral soil surface).

Skeletic (sk) (from Greek *skeletos*, dried out): having ≥ 40% (by volume, related to the whole soil) coarse fragments averaged over a depth of 100 cm from the mineral soil surface or to a limiting layer, whichever is shallower (5).

Akroskeletic (kk) (from Greek *akra*, top)**:** having ≥ 40% of the soil surface covered by fragments that have an average length of their greatest dimension of > 6 cm (stones, boulders and/or large boulders).

Ejectiskeletic (jk) (from Latin *ejicere*, to throw out): having ≥ 40% (by volume, related to the whole soil) coarse fragments of pyroclastic origin (lapilli, bombs and/or blocks), averaged over a depth of 100 cm from the mineral soil surface or to a limiting layer, whichever is shallower (5).

Fractiskeletic (fk) (from Latin *fractus*, broken): having ≥ 40% (by volume, related to the whole soil) coarse fragments plus remnants of a broken-up cemented layer, > 2 mm, averaged over a depth of 100 cm from the mineral soil surface or to a limiting layer, whichever is shallower; and not fulfilling the set of criteria of the Duric, Fractic, Pisoplinthic and Skeletic qualifier (5).

Orthoskeletic (ok) (from Greek *orthos*, right): having:

- ≥ 40% of the soil surface covered by fragments that have an average length of their greatest dimension of > 6 cm (stones, boulders and/or large boulders), *and*
- ≥ 40% (by volume, related to the whole soil) coarse fragments averaged over a depth of 100 cm from the mineral soil surface or to a limiting layer, whichever is shallower (5).

Sodic (so) (from Arabic *suda*, headache - referring to the headache-alleviating properties of sodium carbonate): having a layer, ≥ 20 cm thick and starting ≤ 100 cm from the mineral soil surface, that has ≥ 15% Na plus Mg and ≥ 6% Na on the exchange complex; and not having a *natric horizon* starting ≤ 100 cm from the soil surface (2).

Argisodic (as) (from Latin *argilla*, white clay): having an *argic horizon*, starting ≤ 100 cm from the mineral soil surface, that has ≥ 15% Na plus Mg and ≥ 6% Na on the exchange complex throughout the *argic horizon* or within its upper 40 cm, whichever is thinner (2).

Protosodic (qs) (from Greek *proton*, first): having a layer, ≥ 20 cm thick and starting ≤ 100 cm from the mineral soil surface, that has ≥ 6% Na and < 15% Na plus Mg on the exchange complex; and not having a *natric horizon* starting ≤ 100 cm from the soil surface (2).

Solimovic (sv) (from Latin *solum*, soil, and *movere*, to move): having *solimovic material*, ≥ 20 cm thick and starting at the mineral soil surface (2: Ano- and Panto- only).

Sombric (sb) (from French *sombre*, shade): having a *sombric horizon* starting ≤ 150 cm from the mineral soil surface (2).

Someric (si) (from Spanish *somero*, superficial): having a *mollic* or *umbric horizon*, < 20 cm thick.

Spodic (sd) (from Greek *spodos*, wood ash): having a *spodic horizon* starting ≤ 200 cm from the mineral soil surface (2).

Hyperspodic (jp) (from Greek *hyper*, over): having a *spodic horizon*, ≥ 100 cm thick and starting ≤ 200 cm from the mineral soil surface.

Protospodic (qp) (from Greek *proton*, first): having a layer, starting ≤ 100 cm from the mineral soil surface, that has an Al_{ox} value that is ≥ 1.5 times that of the lowest Al_{ox} value of all the mineral layers above; and not having a *spodic horizon* starting ≤ 200 cm from the mineral soil surface (2).

Spolic (sp) (from Latin *spoliare*, to exploit): having a layer, ≥ 20 cm thick and within 100 cm of the soil surface, with ≥ 20% (by volume, weighted average, related to the whole soil) *artefacts*, ≥ 35% (by volume, weighted average, related to the whole soil) of which consist of industrial products (e.g. mine spoil, dredgings, slag, ash, rubble, etc.) (*in Technosols only*) (2).

Hyperspolic (jj) (from Greek *hyper*, over): having a layer, ≥ 50 cm thick and within 100 cm of the soil surface, with ≥ 35% (by volume, weighted average, related to the whole soil) *artefacts* consisting of industrial products (*in Technosols only*) (2).

Stagnic (st) (from Latin *stagnare*, to flood): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that does not form part of a *hydragric horizon* and that has:

- *stagnic properties* in which the area of reductimorphic features plus the area of oximorphic features is ≥ 25% (weighted average, related to the fine earth plus oximorphic features of any size and any cementation class) of the layer's total area, *and*
- *reducing conditions* for some time during the year in some parts of the layer's volume that has the reductimorphic features (2).

Inclinistagnic (iw) (from Latin *inclinare*, to bow): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that does not form part of a *hydragric horizon* and that has:

- *stagnic properties* in which the area of reductimorphic features plus the area of oximorphic features is ≥ 25% (weighted average, related to the fine earth plus oximorphic features of any size and any cementation class) of the layer's total area, *and*
- *reducing conditions* for some time during the year in some parts of the layer's volume that has the reductimorphic features,
- a slope inclination of ≥ 5% and a subsurface water flow for some time during the year (2).

Protostagnic (qw) (from Greek *proton*, first): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that does not form part of a *hydragric horizon* and that has:

- *stagnic properties* in which the area of reductimorphic features plus the area of oximorphic features is ≥ 10% and < 25% (weighted average, related to the fine earth plus oximorphic features of any size and any cementation class) of the layer's total area, *and*
- *reducing conditions* for some time during the year in some parts of the layer's volume that has the reductimorphic features (2).

Relictistagnic (rw) (from Latin *relictus*, left back): having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that has:

- *stagnic properties* in which the area of oximorphic features is ≥ 10% (weighted average, related to the fine earth plus oximorphic features of any size and any cementation class) of the layer's total area, *and*
- no *reducing conditions* (2).

Subaquatic (sq) (from Latin *sub*, under, and *aqua*, water): being permanently submerged by water not deeper than 200 cm.

Sulfatic (su) (from Latin *sulpur*, sulfur): having a *salic horizon* with a soil solution (1:1 in water) with $[SO_4^{2-}] > 2*[HCO_3^-] > 2*[Cl^-]$ (*in Solonchaks only*).

Sulfidic (sf) (from Latin *sulpur*, sulfur): having *hypersulfidic* or *hyposulfidic material*, ≥ 15 cm thick and starting ≤ 100 cm from the soil surface (2).

Hypersulfidic (js) (from Greek *hyper*, over): having *hypersulfidic material*, ≥ 15 cm thick and starting ≤ 100 cm from the soil surface (2).

Hyposulfidic (ws) (from Greek *hypo*, under): having *hyposulfidic material*, ≥ 15 cm thick and starting ≤ 100 cm from the soil surface (2).

Takyric (ty) (from Turkic languages *takyr*, barren land): having *takyric properties*.

Technic (te) (from Greek *technae*, art): having ≥ 10% (by volume, weighted average, related to the whole soil) *artefacts* in the upper 100 cm from the soil surface or to a limiting layer, whichever is shallower (5).

Hypertechnic (jt) (from Greek *hyper*, over): having ≥ 20% (by volume, weighted average, related to the whole soil) *artefacts* in the upper 100 cm from the soil surface or to a limiting layer, whichever is shallower (5).

Prototechnic (qt) (from Greek *proton*, first): having ≥ 5% (by volume, weighted average, related to the whole soil) *artefacts* in the upper 100 cm from the soil surface or to a limiting layer, whichever is shallower (5).

Tephric (tf) (from Greek *tephra*, pile ash): having within 100 cm of the soil surface one or more layers with *tephric material* with a combined thickness of ≥ 30 cm (2).
Prototephric (qf) (from Greek *proton*, first): having within 100 cm of the soil surface one or more layers with *tephric material* with a combined thickness of ≥ 10 cm (2).
Technotephric (tt) (from Greek *technae*, art): having within 100 cm of the soil surface one or more layers with *tephric material*, consisting predominantly of *artefacts*, with a combined thickness of ≥ 30 cm (2).

Terric (tr) (from Latin *terra*, earth): having a *terric horizon* (2: Panto- only).

Thionic (ti) (from Greek *theion*, sulfur): having a *thionic horizon* starting ≤ 100 cm from the soil surface (2).
Hyperthionic (ji) (from Greek *hyper*, over): having a *thionic horizon* starting ≤ 100 cm from the soil surface and having a pH (1:1 in water) of < 3.5 (2).
Hypothionic (wi) (from Greek *hypo*, under): having a *thionic horizon* starting ≤ 100 cm from the soil surface and having a pH (1:1 in water) of ≥ 3.5 and < 4 (2).

Thixotropic (tp) (from Greek *thixis*, contact, and *tropae*, reversion): having in some layer, within 50 cm of the soil surface, material that changes, under pressure or by rubbing, from a plastic solid into a liquefied stage and back into a solid condition.

Thyric (th) (from Greek *thyreos*, shield): having *technic hard material* starting within > 5 and ≤ 100 cm from the soil surface (1: Epi- and Endo- only).

Tidalic (td) (from English *tide*): affected by tidal water, i.e. located between the line of mean high water springs and the line of mean low water springs.

Tonguic (to) (from English *tongue*): showing tonguing of a *chernic*, *mollic* or *umbric horizon* into an underlying layer.

Toxic (tx) (from Greek *toxon*, bow, referring to arrow poison): having in some layer, within 50 cm of the soil surface, toxic concentrations of organic or inorganic substances other than ions of Al, Fe, Na, Ca and Mg, or having radioactivity dangerous to humans.
Radiotoxic (rx) (from Latin *radius*, ray): having radioactivity, dangerous to humans.
Note: The definition of limit values is the task of governments and not the task of WRB.

Transportic (tn) (from Latin *transportare*, to transport): having at the soil surface or below a recently formed organic surface horizon a layer,
- ≥ 20 cm thick, or
- with a thickness of ≥ 50% of the entire soil if a limiting layer starts ≤ 40 cm from the soil surface,

with soil material containing, if any, < 10% (by volume, related to the whole soil) *artefacts*;
and that has been moved from a source area outside the immediate vicinity by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces (2: Ano- and Panto- only).
Organotransportic (ot) (from Greek *organon*, tool): having at the soil surface or below a recently formed organic surface horizon a layer,

- ≥ 20 cm thick, or
- with a thickness of ≥ 50% of the entire soil if a limiting layer starts ≤ 40 cm from the soil surface,

with *organic material* containing, if any, < 10% (by volume, related to the whole soil) *artefacts;* and that has been moved from a source area outside the immediate vicinity by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces (2: Ano- and Panto- only).

Skeletotransportic (kt) (from Greek *skeletos*, dried out): having at the soil surface or below a recently formed organic surface horizon a layer,

- ≥ 20 cm thick, or
- with a thickness of ≥ 50% of the entire soil if a limiting layer starts ≤ 40 cm from the soil surface,

with soil material containing, if any, < 10% (by volume, related to the whole soil) *artefacts* and ≥ 40% (by volume, weighted average, related to the whole soil) coarse fragments; and that has been moved from a source area outside the immediate vicinity by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces (2: Ano- and Panto- only).

Tsitelic (ts) (from Georgian *tsiteli*, red): having a *tsitelic horizon* starting ≤ 50 cm from the mineral soil surface.

Turbic (tu) (from Latin *turbare*, to disturb): having features of cryogenic alteration (cryoturbation, mixed material, disrupted soil horizons, involutions, organic intrusions, frost heave, separation of coarse from fine materials, cracks, patterned ground etc.) in some layer within 100 cm of the soil surface and above a *cryic horizon* or above a seasonally frozen layer (2: only if clearly recognizable as a layer).

Relictiturbic (rb) (from Latin *relictus*, left back): having features of cryogenic alteration within 100 cm of the soil surface, caused by frost action in the past (2: only if clearly recognizable as layer).

Umbric (um) (from Latin *umbra*, shade): having an *umbric horizon* (2: Ano- and Panto- only).

Anthroumbric (aw) (from Greek *anthropos*, human being): having an *umbric horizon* and *anthric properties* (2: Ano- and Panto- only).

Someriumbric (sw) (from Spanish *somero*, superficial): having an *umbric horizon*, < 20 cm thick.

Tonguiumbric (tw) (from English *tongue*): having an *umbric horizon* that tongues into an underlying layer (2: Ano- and Panto- only; referring to the *umbric horizon*, not to the tongues).

Urbic (ub) (from Latin *urbs*, city): having a layer, ≥ 20 cm thick and within 100 cm of the soil surface, with ≥ 20% (by volume, weighted average, related to the whole soil) *artefacts*, ≥ 35% (by volume, weighted average, related to the whole soil) of which consist of rubble and refuse of human settlements (*in Technosols only*) (2).

Hyperurbic (jx) (from Greek *hyper*, over): having a layer, ≥ 50 cm thick and within 100 cm of the soil surface, with ≥ 35% (by volume, weighted average, related to the whole soil) *artefacts* consisting of rubble and refuse of human settlements (*in Technosols only*) (2).

Uterquic (uq) (from Latin *uterque*, both): having a layer

- with dominant *gleyic properties* and some parts with *stagnic properties*, starting ≤ 75 cm from the mineral soil surface (*in Gleysols only*) (2).
- with dominant *stagnic properties* and some parts with *gleyic properties*, starting ≤ 75 cm from the mineral soil surface (*in Planosols and Stagnosols only*) (2).

Vermic (vm) (from Latin *vermis*, worm): having ≥ 50% (by volume, weighted average) of worm holes, casts, or filled animal burrows in the upper 100 cm of the mineral soil or to a limiting layer, whichever is shallower.

Vertic (vr) (from Latin *vertere*, to turn): having a *vertic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Protovertic (qv) (from Greek *proton*, first): having a *protovertic horizon* starting ≤ 100 cm from the mineral soil surface; and not having a *vertic horizon* starting ≤ 100 cm from the mineral soil surface (2).

Vitric (vi) (from Latin *vitrum*, glass): having within 100 cm of the soil surface

- in *Andosols*, one or more layers with *vitric properties* with a combined thickness of ≥ 30 cm. (2).
- in other soils, one or more layers with *andic* or *vitric properties* with a combined thickness of ≥ 30 cm (in *Cambisols* ≥ 15 cm), of which ≥ 15 cm (in *Cambisols* ≥ 7.5 cm) have *vitric properties* (2).

Wapnic (wa) (from Polish *wapno*, lime): having a *calcic horizon* within *organic material*, starting ≤ 100 cm from the soil surface (2).

Xanthic (xa) (from Greek *xanthos*, yellow): having a *ferralic horizon* that has in a subhorizon, ≥ 30 cm thick and starting ≤ 75 cm from the upper limit of the *ferralic horizon*, in ≥ 90% of its exposed area, a Munsell colour hue of 7.5YR or yellower, a value of ≥ 4 and a chroma of ≥ 5, all moist.

Yermic (ye) (from Spanish *yermo*, desert): having *yermic properties*.

Nudiyermic (ny) (from Latin *nudus*, naked): having *yermic properties* without a desert pavement.

Paviyermic (vy) (from Latin *pavimentum*, floor): having *yermic properties*, including a desert pavement.

6 Codes for the Reference Soil Groups, qualifiers and specifiers

Reference Soil Groups							
Acrisol	AC	Chernozem	CH	Leptosol	LP	Regosol	RG
Alisol	AL	Durisol	DU	Lixisol	LX	Retisol	RT
Andosol	AN	Ferralsol	FR	Luvisol	LV	Solonchak	SC
Anthrosol	AT	Fluvisol	FL	Nitisol	NT	Solonetz	SN
Arenosol	AR	Gleysol	GL	Phaeozem	PH	Stagnosol	ST
Calcisol	CL	Gypsisol	GY	Planosol	PL	Technosol	TC
Cambisol	CM	Histosol	HS	Plinthosol	PT	Umbrisol	UM
Cryosol	CR	Kastanozem	KS	Podzol	PZ	Vertisol	VR

Qualifiers							
Abruptic	ap	Carbonatic	cn	Floatic	ft	Hypereutric	je
Aceric	ae	Carbonic	cx	Fluvic	fv	Hyperferritic	jf
Acric	ac	Chernic	ch	Folic	fo	Hypergarbic	jb
Acroxic	ao	Claric	cq	Fractic	fc	Hypergeric	jq
Activic	at	Chloridic	cl	Fractiskeletic	fk	Hypergypsic	jg
Aeolic	ay	Chromic	cr	Fragic	fg	Hyperhumic	jh
Akrofluvic	kf	Clayic	ce	Garbic	ga	Hyperhydragric	jy
Akromineralic	km	Clayinovic	cj	Gelic	ge	Hypermagnesic	jm
Akroskeletic	kk	Coarsic	cs	Gelistagnic	gt	Hypernatric	jn
Albic	ab	Cohesic	co	Geoabruptic	go	Hyperorganic	jo
Alcalic	ax	Columnic	cu	Geric	gr	Hypersalic	jz
Alic	al	Cordic	cd	Gibbsic	gi	Hypersideralic	jr
Aluandic	aa	Cryic	cy	Gilgaic	gg	Hyperspodic	jp
Andic	an	Cutanic	ct	Glacic	gc	Hyperspolic	jj
Anthraquic	aq	Densic	dn	Gleyic	gl	Hypersulfidic	js
Anthric	ak	Differentic	df	Glossic	gs	Hypertechnic	jt
Anthromollic	am	Dolomitic	do	Greyzemic	gz	Hyperthionic	ji
Anthroumbric	aw	Dorsic	ds	Grumic	gm	Hyperurbic	jx
Archaic	ah	Drainic	dr	Gypsic	gy	Hyposulfidic	ws
Arenic	ar	Duric	du	Gypsofractic	gf	Hypothionic	wi
Arenicolic	ad	Dystric	dy	Gypsiric	gp	Immissic	im
Areninovic	aj	Ejectiskeletic	jk	Haplic	ha	Inclinic	ic
Argisodic	as	Ekranic	ek	Hemic	hm	Inclinigleyic	iy
Aric	ai	Endic	ed	Histic	hi	Inclinistagnic	iw
Arzic	az	Entic	et	Hortic	ht	Infraandic	ia
Biocrustic	bc	Epic	ep	Humic	hu	Infraspodic	is
Brunic	br	Escalic	ec	Hydragric	hg	Irragric	ir
Bryic	by	Eutric	eu	Hydric	hy	Isolatic	il
Calcaric	ca	Eutrosilic	es	Hydrophobic	hf	Isopteric	ip
Calcic	cc	Evapocrustic	ev	Hyperalic	jl	Kalaic	ka
Calcifractic	cf	Ferralic	fl	Hyperartefactic	ja	Lamellic	ll
Cambic	cm	Ferric	fr	Hypercalcic	jc	Lapiadic	ld
Capillaric	cp	Ferritic	fe	Hyperduric	ju	Laxic	la
Carbic	cb	Fibric	fi	Hyperdystric	jd	Leptic	le

Qualifiers							
Lignic	lg	Organotransportic	ot	Protospodic	qp	Somerimollic	sm
Limnic	lm	Ornithic	oc	Protostagnic	qw	Somerirendzic	sr
Limonic	ln	Orthodystric	od	Prototechnic	qt	Someriumbric	sw
Linic	lc	Orthoeutric	oe	Prototephric	qf	Spodic	sd
Lithic	li	Orthofluvic	of	Protovertic	qv	Spolic	sp
Litholinic	lh	Orthomineralic	oi	Puffic	pu	Stagnic	st
Lixic	lx	Orthoskeletic	ok	Pyric	py	Subaquatic	sq
Loamic	lo	Ortsteinic	os	Radiotoxic	rx	Sulfatic	su
Loaminovic	lj	Oxyaquic	oa	Raptic	rp	Sulfidic	sf
Luvic	lv	Oxygleyic	oy	Reductaquic	ra	Takyric	ty
Magnesic	mg	Pachic	ph	Reductic	rd	Technic	te
Manganiferric	mf	Panpaic	pb	Reductigleyic	ry	Technotephric	tt
Mahic	ma	Paviyermic	vy	Relictigleyic	rl	Tephric	tf
Mawic	mw	Pellic	pe	Relictistagnic	rw	Terric	tr
Mazic	mz	Pelocrustic	pq	Relictiturbic	rb	Thionic	ti
Mineralic	mi	Petric	pt	Relocatic	rc	Thixotropic	tp
Minerolimnic	ml	Petrocalcic	pc	Rendzic	rz	Thyric	th
Mochipic	mc	Petroduric	pd	Retic	rt	Tidalic	td
Mollic	mo	Petrogypsic	pg	Rheic	rh	Tonguic	to
Mulmic	mm	Petroplinthic	pp	Rhodic	ro	Tonguichernic	tc
Murshic	mh	Petrosalic	ps	Rockic	rk	Tonguimollic	tm
Muusic	mu	Pisoplinthic	px	Rubic	ru	Tonguiumbric	tw
Naramic	nr	Placic	pi	Rustic	rs	Totilamellic	ta
Natric	na	Plaggic	pa	Salic	sz	Toxic	tx
Nechic	ne	Plinthic	pl	Sapric	sa	Transportic	tn
Neobrunic	nb	Posic	po	Saprolithic	sh	Tsitelic	ts
Neocambic	nc	Pretic	pk	Sideralic	se	Turbic	tu
Nitic	ni	Profondic	pn	Silandic	sn	Umbric	um
Novic	nv	Profundihumic	dh	Siltic	sl	Urbic	ub
Nudiargic	ng	Protic	pr	Siltinovic	sj	Uterquic	uq
Nudilithic	nt	Protoandic	qa	Skeletic	sk	Vermic	vm
Nudinatric	nn	Protoargic	qg	Skeletofolic	ko	Vertic	vr
Nudipetric	np	Protocalcic	qc	Skeletohistic	kh	Vitric	vi
Nudiyermic	ny	Protogleyic	qy	Skeletotransportic	kt	Wapnic	wa
Ochric	oh	Protogypsic	qq	Sodic	so	Xanthic	xa
Oligoeutric	ol	Protokalaic	qk	Solimovic	sv	Yermic	ye
Ombric	om	Protosalic	qz	Sombric	sb		
Organolimnic	oo	Protosodic	qs	Someric	si		

Specifiers							
Amphi	..m	Endo	..n	Kato	..k	Supra	..s
Ano	..a	Epi	..p	Panto	..e	Thapto	..b
Bathy	..d			Poly	..y		

Combinations with the Novic qualifier (see Chapter 2.4, Buried soils)							
Aeoli-Novic	nva	Solimovi-Novic	nvs	Tephri-Novic	nvv	Transporti-Novic	nvp
Fluvi-Novic	nvf	Techni-Novic	nvt				

Note: The codes for the combinations with subqualifiers of the Novic qualifier are constructed accordingly, e.g., Aeoli-Siltinovic (sja).

Rules for the use of the codes for naming soils

At the first level of classification, the code of the RSG stands alone.
At the second level, the code starts with the RSG,
followed by a '-',
followed by the principal qualifiers, if several ones apply, with a '.' between them, according to the list from top to bottom,
if applicable, followed by a '-',
followed by the supplementary qualifiers related to texture, if several ones apply, with a '.' between them, in the sequence from the top to the bottom of the profile,
if applicable, followed by a '-',
followed, by the other supplementary qualifiers, if several ones apply, with a '.' in between them, in alphabetical order of the qualifier names (not in alphabetical order of their codes),
if applicable, followed by a '-',
followed by qualifiers that are not in the list for the particular RSG.
Subqualifiers (qualifiers combined with specifiers) are placed in the order of the qualifiers as if they were used without the specifier. Exception: If used with a principal qualifier, the Proto-, Bathy- and Thapto-subqualifiers must shift to the supplementary qualifiers.
If one group of qualifiers is empty, the '-' is still included, if one of the following groups is not empty.

The resulting scheme is as follows:
RSG{-}[PQ1[.PQ2]etc]{-}[TQ1[.TQ2]etc]{-}[SQ1[.SQ2]etc]{-}[NQ1[.NQ2]etc]

With:
PQ = principal qualifier, with or without added specifiers,
TQ = supplementary qualifier related to texture, with or without added specifiers,
SQ = other supplementary qualifier, with or without added specifiers,
NQ = qualifier not listed for the particular RSG, with or without added specifiers;
etc = further qualifiers can be added in the same way if necessary;
elements in [] are listed if they apply;
elements in {} are necessary if elements follow.

Examples of the use of the codes for naming soils

Albic Stagnic Luvisol (Episiltic, Katoclayic, Bathysiltic, Cutanic, Differentic, Epic, Ochric):
LV-st.ab-slp.cek.sld-ct.df.ep.oh
Hemic Folic Endorockic Histosol (Dystric):
HS-rkn.fo.hm--dy
Haplic Ferralsol (Pantoloamic, Dystric, Endic, Humic, Bathypetroplinthic, Posic):
FR-ha-loe-dy.ed.hu.ppd.po
Calcaric Skeletic Pantofluvic Fluvisol (Pantoarenic, Ochric):
FL-fve.sk.ca-are-oh
Dystric Umbric Aluandic Andosol (Pantosiltic, Thaptohistic, Hyperhumic):
AN-aa.um.dy-sle-hib.jh
Isolatic Ekranic Technosol (Supraarenic, Supracalcaric):
TC-ek.il-ars-cas
Dystric Arenosol (Bathyspodic):
AR-dy--sdd

Rules for the use of the codes for creating map legends

At the first scale level, the code of the RSG stands alone.
At the second and third scale level, the code starts with the RSG,
followed by a ‘-’,
followed by the principal qualifiers (number according to the scale level) according to the list from top to bottom, with a ‘.’ between them.
If elective qualifiers are added,
a ‘-’ is added,
followed by the elective qualifiers, with a ‘.’ between them (the principal qualifiers are placed first, and of them, the first applicable qualifier is placed first, and the sequence of any supplementary qualifiers added is decided by the soil scientist who makes the map).
If according to the scale level no principal qualifier has to be added, the ‘-’ is still included, if any elective qualifier is added.
If codominant or associated soils are indicated, the words ‘dominant:’, ‘codominant:’ and ‘associated:’ are written before the code of the soil.

The resulting scheme is as follows:
RSG{-}[PQ1[.PQ2]]{-}[EQ1[.EQ2]etc]

With:
PQ = principal qualifier,
EQ = elective qualifier;
etc = further qualifiers can be added in the same way if necessary;
elements in [] are listed if they apply;
elements in {} are necessary if elements follow.

Examples of the use of the codes for creating map legends

Umbric Geric Xanthic Ferralsols (Clayic, Dystric, Endic, Humic):
first scale level: FR
second scale level: FR-xa
third scale level: FR-xa.gr
If elective qualifiers are added: examples:
first scale level: FR--ce
second scale level: FR-xa-ce
third scale level: FR-xa.gr-um.ce.dy

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8 Annex 1: Field Guide

This field guide helps describe soils. It provides all field characteristics needed for WRB classification and some other general field characteristics. This field guide is not supposed to be a comprehensive manual. People using this guide must have basic knowledge in soil science and experience in the field. In many soils, some of the listed characteristics are not present. Every characteristic must be reported in the soil description sheet (Annex 4, Chapter 11) using the provided codes.

The field guide consists of six consecutive parts:

1. Preparation work and general rules
2. General data and description of soil-forming factors
3. Description of surface characteristics
4. Description of layers
5. Sampling
6. References

Figure 8.1: Ideal soil scientists

8.1 Preparation work and general rules

8.1.1 Exploration of an area of interest with auger and spade

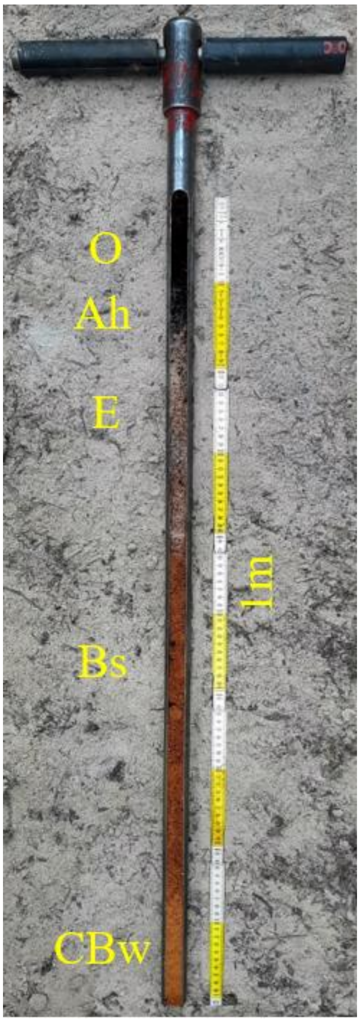


Figure 8.2: Pürckhauer auger profile

Select your area of interest and give it a distinct name, e.g., *Gombori Pass*. Then select a location. For further exploration, use a *Pürckhauer* or an *Edelman* auger. If using a Pürckhauer auger, drive it into the soil vertically with a plastic hammer. Occasionally, turn the auger with the help of the turning bar, especially in clay-rich soils. If the auger hits a rock or big stone, take it out. You may try again a small distance apart but be careful not to damage the auger. Drive the auger in to a depth of 1 m if possible. If not, note the actual depth that was reached. To take it out, turn it while pulling.

Now place the auger onto the ground. Cut the protruding soil material with a knife and remove it to the side. Avoid contaminating one layer with the removed material from another. Be aware that compaction inside the auger may have occurred; the layer depths may therefore not be accurate. Place a folding ruler aside the auger according to the actually reached depth (Figure 8.2).

In most cases, the topsoil falls out of the auger. To investigate it in more detail, always make a mini-profile close to where the auger was driven in. It should be at least 25 cm deep and wide, and the profile walls should be vertical and smooth. Now place a folding ruler inside the profile in such a way that point 0 is at the soil surface (see Chapter 8.3.1). For later reconstruction, it may help to take a picture of the mini-profile (Figure 8.3).

The characteristics that can be described from the soil material in the auger are marked with an asterisk (*) in Chapter 8.4.

Figure 8.3: Mini-profile

8.1.2 Preparation of a soil profile

The soil profile should be at least 1 m deep or reach the parent material. On a slope, unless the parent material starts at smaller depth, the profile depth (Figure 8.4) should be 1 m / cos(α). For the decision if the thickness and depth criteria of the WRB are fulfilled and when calculating element stocks (Prietzel & Wiesmeier, 2019), the layer thickness perpendicular to the slope is needed. This is calculated multiplying the vertical thickness by cos(α).

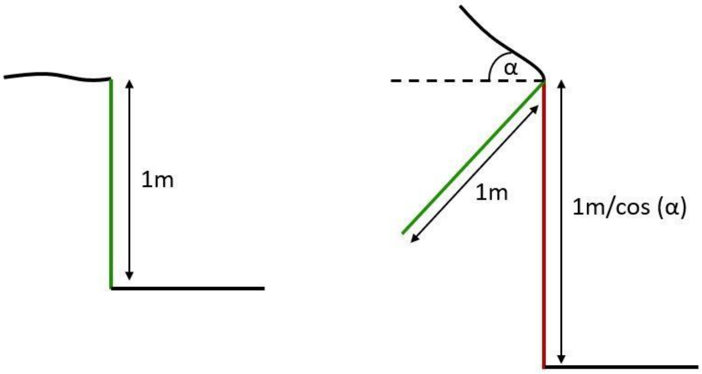


Figure 8.4: Correct profile depth when terrain is inclined

The profile should be 1 m wide. If on a slope, the profile wall must be parallel to the contour lines. The material should be piled up to the left and/or right side of the profile and must not be placed on top side of the profile (the side of the profile wall). Never walk or place tools on the side of the profile wall. It is recommended to collect the soil material on two tarps, topsoil and subsoil separately. When refilling the soil profile later, you should first fill in the subsoil and then the topsoil.

Carefully prepare the profile wall: it must be strictly vertical and smooth. Roots should be cut directly at the profile wall. Use an appropriate tool to clean the profile wall horizontally and avoid vertical smearing. Place the measuring tape in such a way that point 0 is at the soil surface (see Chapter 8.3.1). It should be at one side but not touch the side walls. It must be strictly vertical and plane. It may help to weight the bottom end of the tape with a stone or stick. Take a photo. Hold the camera perpendicularly to the profile wall (Figure 8.5). Avoid any inclination. Also take at least one picture of the surrounding terrain and vegetation (Figure 8.6), e.g., the tree canopy. Make sure you will be able to associate profile and photo later. If possible, save and name the pictures the same day they are taken.

If you describe a soil profile that has been dug some time ago, the topsoil may be disturbed. To describe the humus forms, you need a fresh mini-profile nearby the soil profile.

Figure 8.5: Ideal soil profile. Always take the photo perpendicular to the profile wall

Figure 8.6: The setting of the profile in the landscape

8.2 General data and description of soil-forming factors

This Chapter refers to some general data and to the soil-forming factors climate, landform and vegetation. Other soil-forming factors are described with the layer description.

8.2.1 Date and authors

Report the date of description and the names of the describing authors.

8.2.2 Location

Give the location a name and report it; e.g., *Gombori Pass 1*.

Report the GPS coordinates.

Report the altitude above sea level (a.s.l.); e.g., *106 m*.

8.2.3 Landform and topography

This Chapter refers to the large-scale topography. For local surface unevenness, see Chapter 8.3.11.

Gradient

Report the ground surface inclination with respect to the horizontal plane. If the profile lies on a flat surface, the gradient is 0%. If it lies on a slope, make 2 records, one upslope and one downslope; e.g., *upslope: 18%, downslope: 16%.*

Slope aspect

If the profile lies on a slope, report the compass direction that the slope faces, viewed downslope; e.g., *225°*.

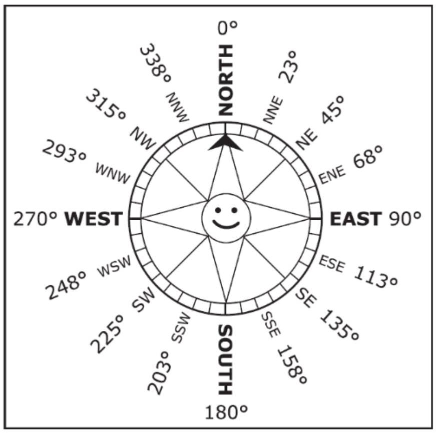


Figure 8.7: Slope aspect, Schoeneberger et al. (2012), 1-5

Slope shape

If the profile lies on a slope, report the slope shape in 2 directions: up-/downslope (perpendicular to the elevation contour, i.e. the vertical curvature) and across slope (along the elevation contour, i.e. the horizontal curvature); e.g., *Linear*, *Convex* or *Concave*.

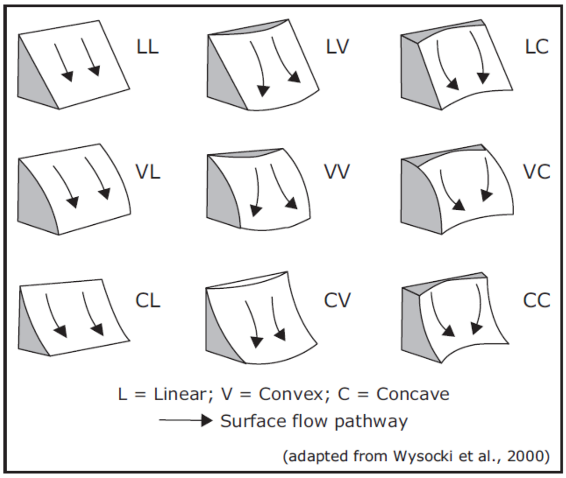


Figure 8.8: Slope Shape, Schoeneberger et al. (2012), 1-6

Position of the soil profile (related to topography)

If the profile lies in an uneven terrain, report the profile position.

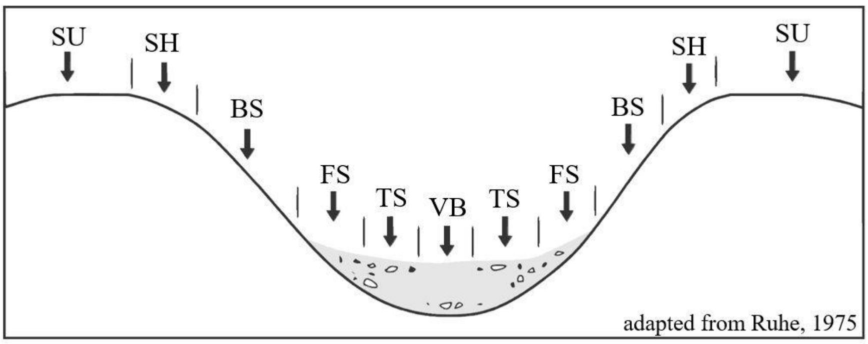


Figure 8.9: Position of the profile, Schoeneberger et al. (2012), 1-7, modified (basin not included)

Table 8.1: Position of the profile, Schoeneberger et al. (2012), 1-7, modified

Position	Code
Summit	SU
Shoulder	SH
Backslope	BS
Footslope	FS
Toeslope	TS
Valley bottom	VB
Basin with outflow	OB
Endorheic basin	EB

8.2.4 Climate and weather

Climate

Report the climate according to Köppen (1936) and the ecozones according to Schultz (2005, adapted). The term 'summer' refers to the season with high solar altitude and the term 'winter' to the season with low solar altitude.

Table 8.2: Climate according to Köppen (1936)

Climate	Code
Tropical climates	A
Tropical rainforest climate	Af
Tropical savanna climate with dry-winter characteristics	Aw
Tropical savanna climate with dry-summer characteristics	As
Tropical monsoon climate	Am
Dry climates	B
Hot arid climate	BWh
Cold arid climate	BWc
Hot semi-arid climate	BSh
Cold semi-arid climate	BSc
Temperate climates	C
Mediterranean hot summer climate	Csa
Mediterranean warm/cool summer climate	Csb
Mediterranean cold summer climate	Csc
Humid subtropical climate	Cfa
Oceanic climate	Cfb
Subpolar oceanic climate	Cfc
Dry-winter humid subtropical climate	Cwa
Dry-winter subtropical highland climate	Cwb
Dry-winter subpolar oceanic climate	Cwc

Continental climates	D
Hot-summer humid continental climate	Dfa
Warm-summer humid continental climate	Dfb
Subarctic climate	Dfc
Extremely cold subarctic climate	Dfd
Monsoon-influenced hot-summer humid continental climate	Dwa
Monsoon-influenced warm-summer humid continental climate	Dwb
Monsoon-influenced subarctic climate	Dwc
Monsoon-influenced extremely cold subarctic climate	Dwd
Mediterranean-influenced hot-summer humid continental climate	Dsa
Mediterranean-influenced warm-summer humid continental climate	Dsb
Mediterranean-influenced subarctic climate	Dsc
Mediterranean-influenced extremely cold subarctic climate	Dsd
Polar and alpine climates	E
Tundra climate	ET
Ice cap climate	EF

Table 8.3: Ecozones according to Schultz (2005, adapted)

Ecozone	**Code**
Tropics with year-round rain	TYR
Tropics with summer rain	TSR
Dry tropics and subtropics	TSD
Subtropics with year-round rain	SYR
Subtropics with winter rain (Mediterranean climate)	SWR
Humid mid-latitudes	MHU
Dry mid-latitudes	MDR
Boreal zone	BOR
Polar-subpolar zone	POS

Season of description

Report the season of the description. Vegetation can best be described in the season of full vegetation development.

Table 8.4: Season of description

Ecozone	**Season**	**Code**
SYR, SWR, MHU, MDR, BOR, POS	Spring	SP
	Summer	SU
	Autumn	AU
	Winter	WI
TSR	Wet season	WS
	Dry season	DS
TYR, TSD	No significant seasonality for plant growth	NS

Weather conditions

Report the current and past weather conditions.

Table 8.5: Current weather conditions, Schoeneberger et al. (2012), 1-1

Current weather conditions	Code
Sunny/clear	SU
Partly cloudy	PC
Overcast	OV
Rain	RA
Sleet	SL
Snow	SN

Table 8.6: Past weather conditions, FAO (2006), Table 2

Past weather conditions	Code
No rain in the last month	NM
No rain in the last week	NW
No rain in the last 24 hours	ND
Rain but no heavy rain in the last 24 hours	RD
Heavy rain for some days or excessive rain in the last 24 hours	RH
Extremely rainy or snow melting	RE

8.2.5 Vegetation and land use

This Chapter refers to all kinds of plant cover from completely natural to completely human-made. It is not a vegetation survey, and only the really soil-relevant characteristics are reported. If the land is cultivated as cropland or grassland, the cultivation type is reported. In all other cases, the vegetation type is reported. Observe an area (10 m x 10 m, if possible) with the profile at its centre.

Vegetation strata

The following strata are relevant.

Table 8.7: Vegetation strata, National Committee on Soil and Terrain (2009), 79, modified

Criterion	Stratum	Code
Ground vegetation	Ground stratum	GS
If both ground stratum and upper stratum are present, you may define a mid-stratum between the upper stratum and the ground stratum	Mid-stratum	MS
Tallest plants (only if crown cover ≥ 5%)	Upper stratum	US

Vegetation type or cultivation type

If the land is not cultivated, report the vegetation type according to Table 8.8, for each stratum separately; if more than one type occurs in the same stratum, report up to three, the dominant one first. If the land is cultivated, report the cultivation type according to Table 8.9; cultivated land may show several strata, but they are not reported separately.

Table 8.8: Vegetation type, National Committee on Soil and Terrain (2009), 88-93, modified

Life form	Vegetation type	Code
Aquatic	Algae: fresh or brackish	AF
	Algae: marine	AM
	Higher aquatic plants (woody or non-woody)	AH
Surface crusts	Biological crust (of cyanobacteria, algae, fungi, lichens and/or mosses)	CR

Terrestrial non-woody plants	Fungi	NF
	Lichens	NL
	Mosses (non-peat)	NM
	Peat	NP
	Grasses and/or herbs	NG
Terrestrial woody plants	Heath or dwarf shrubs	WH
	Evergreen shrubs	WG
	Seasonally green shrubs	WS
	Evergreen trees (mainly not planted)	WE
	Seasonally green trees (mainly not planted)	WT
	Plantation forest, not in rotation with cropland or grassland	WP
	Plantation forest, in rotation with cropland or grassland	WR
None (barren)	Water, rock, or soil surface with < 0.5% vegetation cover	NO

Table 8.9: Cultivation type

Cultivation type	**Code**
Simultaneous agroforestry system with trees and perennial crops	ACP
Simultaneous agroforestry system with trees and annual crops	ACA
Simultaneous agroforestry system with trees, perennial and annual crops	ACB
Simultaneous agroforestry system with trees and grassland	AGG
Simultaneous agroforestry system with trees, crops and grassland	ACG
Pasture on (semi-)natural vegetation	GNP
Intensively-managed grassland, pastured	GIP
Intensively-managed grassland, not pastured	GIN
Perennial crop production (e.g. food, fodder, fuel, fiber, ornamental plants)	CPP
Annual crop production (e.g. food, fodder, fuel, fiber, ornamental plants)	CPA
Fallow, less than 12 months, with spontaneous vegetation	FYO
Fallow, at least 12 months, with spontaneous vegetation	FOL
Fallow, all plants constantly removed (dry farming)	FDF

Vegetation height, cover and taxa

For non-cultivated land, report the following characteristics:

- Report the average height and the maximum height in m above ground for each stratum separately.
- Report the vegetation cover. For the upper stratum and the mid-stratum, report the percentage (by area) of the crown cover. For the ground stratum, report the percentage (by area) of the ground cover.
- Report up to three important species per stratum, e.g., *Fagus orientalis*. If you do not know the species, report the next higher taxonomic rank.

Actual or last cultivated species

For cultivated land, report the actual cultivated species using the scientific name, e.g., *Zea mays*. If currently under fallow, report the last species and indicate month and year of harvest or of cultivation cessation. If more than one species is/was grown simultaneously, report up to three in the sequence of the area covered, starting with the species that covers the largest area; this includes tree species in simultaneous agroforestry systems.

Rotational cultivated species

For cultivated land, report the species that have been cultivated in the last five years in rotation with the actual or last species. Report up to three in the sequence of frequency, starting with the most frequent species; this includes tree species in rotational agroforestry systems.

Special techniques to enhance site productivity

Report the techniques that refer to the surrounding area of the soil profile. Techniques that affect certain soil layers are reported for the respective layer. Techniques that cause surface unevenness have to be reported in Chapter 8.3.11, additionally. If more than one type is present, report up to three, the dominant one first.

Table 8.10: Special techniques to enhance site productivity

Type	Code
Drainage by open canals	DC
Underground drainage	DU
Wet cultivation	CW
Irrigation	IR
Raised beds	RB
Human-made terraces	HT
Local raise of land surface	LO
Other	OT
None	NO

8.3 Description of surface characteristics

Surface characteristics can be detected on the soil surface without looking into a soil profile.

8.3.1 Soil surface

A **litter layer** is a loose layer that contains > 90% (by volume, related to the fine earth plus all dead plant residues) recognizable dead plant tissues (e.g. undecomposed leaves). Dead plant material still connected to living plants (e.g. dead parts of *Sphagnum* mosses) is not regarded to form part of a litter layer. The **soil surface** (0 cm) is by convention the surface of the soil after removing, if present, the litter layer and, if present, below a layer of living plants (e.g. living mosses). The **mineral soil surface** is the upper limit of the uppermost mineral horizon (see Chapter 2.1, General rules, and see Chapter 8.4.4).

8.3.2 Litter layer

Observe an area of 5 m x 5 m with the profile at its centre. Report the average and the maximum thickness of the litter layer in cm (see Chapter 8.3.1). If there is no litter layer, report 0 cm as thickness.

8.3.3 Rock outcrops

Rock outcrops are exposures of bedrock. Observe an area (10 m x 10 m if possible) with the profile at its centre. Report the percentage of the area that is covered by rock outcrops. Also report in m the average distance between rock outcrops and their size (average length of the greatest dimension).

8.3.4 Coarse surface fragments

Coarse surface fragments are loose fragments lying at the soil surface, including those partially exposed. Observe an area (5 m x 5 m if possible) with the profile at its centre. The Table indicates the average length of the greatest dimension in cm.

Table 8.11: Size of coarse surface fragments, FAO (2006), Table 15

Size (cm)	Size class	Code
> 0.2 - 0.6	Fine gravel	F
> 0.6 - 2	Medium gravel	M
> 2 - 6	Coarse gravel	C
> 6 - 20	Stones	S
> 20 - 60	Boulders	B
> 60	Large boulders	L
No coarse surface fragments		N

Report the total percentage of the area that is covered by coarse surface fragments. In addition, report at least one and up to three size classes and report the percentage of the area that is covered by the coarse surface fragments of the respective size class, the dominant one first.

8.3.5 Desert features

Coarse fragments that are constantly exposed to wind-blown sand may be affected by abrasion, etching and polishing, which results in even surfaces with sharp edges. These fragments are called ventifacts (windkanters), and their totality is called desert pavement. Observe an area of 5 m x 5 m with the profile at its centre and report the percentage of ventifacts out of the coarse fragments > 2 cm (greatest dimension).

Coarse fragments may show chemical weathering, which may lead to the formation of oxides and an intense colour at their upper surfaces, whereas there is no such weathering and therefore the original rock colour at their lower surfaces. This intense colour at the upper surfaces is called desert varnish. Observe an area of 5 m x 5 m with the profile at its centre and report the percentage of coarse fragments > 2 cm (greatest dimension) featuring desert varnish.

8.3.6 Patterned ground

Patterned ground is the result of material sorting due to freeze-thaw cycles in permafrost regions. Report the sorting of coarse fragments > 6 cm (greatest dimension) at the soil surface.

Table 8.12: Patterned ground

Form	Code
Rings	R
Polygons	P
Stripes	S
None	N

8.3.7 Surface crusts

Surface crusts are described as layers in Chapter 8.4.31 and further explained there. The area covered is described here. Observe an area (5 m x 5 m if possible) with the profile at its centre. Report the percentage of the area that has a surface crust.

8.3.8 Surface cracks

Cracks are fissures other than those attributed to soil structure (see Chapter 8.4.10). If surface cracks are present, report the average width of the cracks. If the soil surface between cracks of larger width classes is regularly divided by cracks of smaller width classes, report the two width classes. If different width classes occur randomly, just report the dominant one. The continuity of cracks to a greater depth is reported with the layer description (see Chapter 8.4.13). For every width class, report the average distance between the cracks and the spatial arrangement and persistence of the cracks.

Width

Table 8.13: Width of surface cracks, FAO (2006), Table 21

Width (cm)	Width class	Code
≤ 1	Very fine	VF
> 1 - 2	Fine	FI
> 2 - 5	Medium	ME
> 5 - 10	Wide	WI
> 10	Very wide	VW
No surface cracks		NO

Distance between surface cracks

Table 8.14: Distance between surface cracks, FAO (2006), Table 21, modified

Distance (cm)	Distance class	Code
≤ 0.5	Tiny	TI
> 0.5 - 2	Very small	VS
> 2 - 5	Small	SM
> 5 - 20	Medium	ME
> 20 - 50	Large	LA
> 50 -200	Very large	VL
> 200 - 500	Huge	HU
> 500	Very huge	VH

Spatial arrangement of surface cracks

Table 8.15: Spatial arrangement of surface cracks

Spatial arrangement	Code
Polygonal	P
Non-polygonal	N

Persistence of surface cracks

Table 8.16: Persistence of surface clacks

Criterion	Code
Reversible (open and close with changing moisture, e.g., in Vertisols and in soils with the Vertic or the Protovertic qualifier)	R
Irreversible (persist year-round, e.g., drained polder cracks, cracks in cemented layers)	I

8.3.9 Presence of water

Report the presence of water above the soil surface. For wet cultivation and irrigation, see Chapter 8.2.5. If water of more than one origin occurs above the soil surface, report the dominant one.

Table 8.17: Water above the soil surface

Criterion	Code
Permanently submerged by seawater (below mean low water springs)	MP
Tidal area (between mean low and mean high water springs)	MT
Occasional storm surges (above mean high water springs)	MO
Permanently submerged by inland water	FP
Submerged by remote flowing inland water at least once a year	FF
Submerged by remote flowing inland water less than once a year	FO
Submerged by rising local groundwater at least once a year	GF
Submerged by rising local groundwater less than once a year	GO
Submerged by local rainwater at least once a year	RF
Submerged by local rainwater less than once a year	RO
Submerged by inland water of unknown origin at least once a year	UF
Submerged by inland water of unknown origin less than once a year	UO
None of the above	NO

8.3.10 Water repellence

Dry soil surfaces may be water-repellent (hydrophobic). Report the water repellence only if the soil surface is dry. Place some water on the soil surface and measure the time until it infiltrates.

Table 8.18: Water repellence

Criterion	Code
Water stands for ≥ 60 seconds	R
Water infiltrates completely within < 60 seconds	N

8.3.11 Surface unevenness

Natural surface unevenness

This paragraph refers to unevenness resulting from soil-forming processes, not associated with erosion, deposition or human activity. Human-made surface unevenness and erosion are reported in the following paragraphs. Deposition is regarded to be a feature of the layers (see Chapter 8.4). Report surface unevenness with an average height difference ≥ 5 cm. Report the type, the average height difference, the average diameter of the elevated areas and the average distance between the height maxima. Give all values in m.

Table 8.19: Types of natural surface unevenness

Criterion	Code
Unevenness caused by permafrost (palsa, pingo, mud boils, thufurs etc.)	P
Unevenness caused by shrink-swell clays (gilgai relief)	G
Other	O
None	N

Human-made surface unevenness

Report up to two types of human-made surface unevenness with an average height difference of ≥ 5 cm, the dominant one first. Report only if it shows a repeating pattern. Single characteristics, e.g. a single heap, are not reported. For terraces, report the average height of the terrace wall. For all other features, report the average difference between the highest and the lowest points, the average width/length of the feature, and the average distance between the depth/height maxima. Give all values in cm.

Table 8.20: Types of human-made surface unevenness

Type	Code
Human-made terraces	HT
Raised beds	RB
Other longitudinal elevations	EL
Polygonal elevations	EP
Rounded elevations	ER
Drainage canals	CD
Irrigation canals	CI
Other canals	CO
Polygonal holes	HP
Rounded holes	HR
Other	OT
None	NO

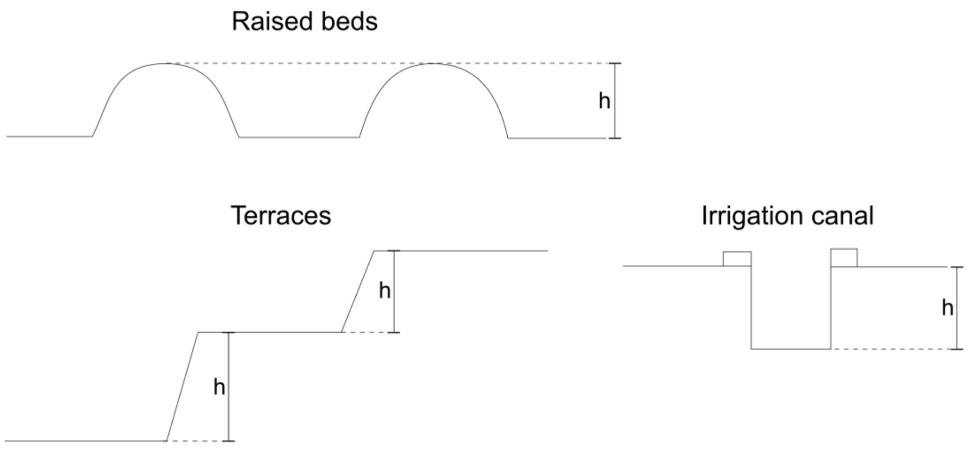


Figure 8.10: Human-made surface alterations

Surface unevenness caused by erosion

This paragraph refers to erosion phenomena with an average height difference of ≥ 5 cm. Report category, degree, and activity.

Table 8.21: Categories of erosion, FAO (2006), Table 16

Category	Code
Water erosion	
Sheet erosion	WS
Rill erosion	WR
Gully erosion	WG
Tunnel erosion	WT
Aeolian (wind) erosion	
Shifting sands	AS
Other types of wind erosion	AO
Water and aeolian (wind) erosion	WA
Mass movement (landslides and similar phenomena)	MM
Erosion, not categorized	NC
No evidence of erosion	NO

Table 8.22: Degree of erosion, FAO (2006), Table 18

Criterion	Degree	Code
Some evidence of damage to surface layers, original ecological functions largely intact	Slight	S
Clear evidence of removal of surface layers, original ecological functions partly destroyed	Moderate	M
Surface layers completely removed and subsurface layers exposed, original ecological functions largely destroyed	Severe	V
Substantial removal of deeper subsurface layers, original ecological functions fully destroyed (badlands)	Extreme	E

Table 8.23: Activity of erosion, FAO (2006), Table 19

Criterion	Code
Active at present	PR
Active in recent past (within the last 100 years)	RE
Active in historical times	HI
Period of activity not known	NK

Position of the soil profile (related to surface unevenness)

Report, where the soil profile is located.

Table 8.24: Position of the soil profile, if the soil surface is uneven

Position	Code
On the high	H
On the slope	S
In the low	L
On an unaffected surface	E

8.3.12 Technical surface alterations

This Chapter refers to technical surface alterations that do not cause or enhance surface unevenness. For surface unevenness see Chapter 8.3.11. Report the technical surface alterations.

Table 8.25: Technical surface alterations

Type	Code
Sealing by concrete	SC
Sealing by asphalt	SA
Other types of sealing	SO
Topsoil removal	TR
Levelling	LV
Other	OT
None	NO

8.4 Description of layers

8.4.1 Identification of layers and layer depths

A **soil layer** is a zone in the soil, approximately parallel to the soil surface, with properties different from layers above and/or below it. If at least one of these properties is the result of soil-forming processes, the layer is called a **soil horizon**. In the following, the term 'layer' is preferred to include layers, in which soil-forming processes did not occur.

A soil layer is identified by certain observable characteristics. Among these characteristics are:

- Matrix colour
- Redoximorphic features
- Texture
- Coarse fragments
- Artefacts
- Bulk density
- Structure
- Coatings and bridges
- Cracks
- Carbonates
- Secondary carbonates
- Secondary gypsum
- Secondary silica
- Cementation
- Water saturation
- Volcanic glasses
- C_{org} content
- Human alterations

Wherever you observe a major difference in at least one of these characteristics, set a layer boundary. Whenever a layer is too thick (e.g. > 30 cm), it may be wise to subdivide it into two or more layers of more or less equal thickness for description. In certain soils, it may also be wise to add additional layer limits at depths, which you may need to check for the presence or absence of a diagnostic horizon (e.g. 20 cm to check *mollic* or *umbric horizons*). Alluvial sediments and tephra layers may be finely stratified. It may be appropriate to combine several such strata to one layer for description. In all other cases, different geological strata must not be combined to one layer.

In the following headings, the (o), the (m), and the (o, m) indicate, whether the described characteristic has to be reported in organic or in mineral layers or in both (see Chapter 8.4.4). For organotechnic layers, the user decides, which characteristics have to be described. The asterisk (*) informs that the characteristic can also be reported in a *Pürckhauer* auger.

The layers are numbered consecutively from the soil surface (see Chapter 8.3.1) downwards. Report the upper and lower depth for every layer. If the lower depth of the last layer is unknown, report the depth of the profile with the + symbol as the layer's lower depth.

The following principles have to be considered for description (see General rules, Chapter 2.1):

1. All data refer to the fine earth, unless stated otherwise. The **fine earth** comprises the soil constituents

≤ 2 mm. The **whole soil** comprises fine earth, coarse fragments, *artefacts*, cemented parts, and dead plant residues of any size.
2. All data are given **by mass**, unless stated otherwise.

8.4.2 Homogeneity of the layer (o, m)

Layer consisting of different parts

If a layer consists of two or more different parts that do not form horizontal layers but can easily be distinguished, describe them separately. Use separate lines in the Soil Description Sheet (Annex 4, Chapter 11) and report the percentage (by exposed area, related to the whole soil) of each part. Examples are layers with *retic properties* (see Chapter 8.4.18), with cryogenic alteration (see Chapter 8.4.34) or with remodelling by single ploughing (see Chapter 8.4.39). The separation is not recommended, if there is just a wavy boundary (as typical, e.g., for *chernic horizons* or for eluvial horizons in Podzols, see Chapter 8.4.5) or if there are just some additions of materials (see Chapter 8.4.39).

Layer composed of several strata of alluvial sediments or of tephra

Alluvial strata comprise fluviatile, lacustrine and marine deposits. Tephra strata have a significant amount of pyroclasts. Report the presence of alluvial strata and of tephra strata within the described layer.

Table 8.26. Presence of strata within a layer

Criterion	Code
Layer is composed of two or more alluvial strata	A
Layer is composed of two or more tephra strata	T
Layer is composed of two or more alluvial strata containing tephra	B
Layer is not composed of different strata	N

8.4.3 Water

Water saturation (o, m)

Report the water saturation.

Table 8.27: Types of water saturation

Criterion	Code
Saturated by seawater for ≥ 30 consecutive days	MS
Saturated by seawater according to tidal changes	MT
Saturated by groundwater or flowing water for ≥ 30 consecutive days with water that has an electrical conductivity of ≥ 4 dS m^{-1}	GS
Saturated by groundwater or flowing water for ≥ 30 consecutive days with water that has an electrical conductivity of < 4 dS m^{-1}	GF
Saturated by rainwater for ≥ 30 consecutive days	RA
Saturated by water from melted ice for ≥ 30 consecutive days	MI
Pure water, covered by floating organic material	PW
None of the above	NO

Soil water status (m) (*)

Check the soil water status of non-saturated layers. Spray the profile wall with water and observe the colour change. Then crush a sample and report the behaviour.

Table 8.28: Soil water status, FAO (2006), Table 57, modified

Moistening	Crushing	Moisture class	Code
Going very dark	Dusty or hard	Very dry	VD
Going dark	Makes no dust	Dry	DR
Going slightly dark	Makes no dust	Slightly moist	SM
No change of colour	Makes no dust	Moist	MO
No change of colour	Drops of water	Wet	WE

8.4.4 Organic, organotechnic and mineral layers

We distinguish the following layers (see Chapter 3.3):

- Organic layers consist of organic material.
- Organotechnic layers consist of organotechnic material.
- Mineral layers are all other layers.

An organic or organotechnic layer is called hydromorphic, if water saturation lasts ≥ 30 consecutive days in most years or if it has been drained. Otherwise, it is called terrestrial. Hydromorphic organic layers comprise peat and organic limnic material. Report, whether a layer is organic, organotechnic or mineral and, if organic or organotechnic, whether it is hydromorphic or terrestrial. The distinction is preliminary and may have to be corrected according to laboratory analyses.

Table 8.29: Organic (hydromorphic and terrestrial), organotechnic and mineral layers

Criterion	Code
Organic hydromorphic	OH
Organic terrestrial	OT
Organotechnic hydromorphic	TH
Organotechnic terrestrial	TT
Mineral	MI

8.4.5 Layer boundaries (o, m)

Distinctness of the layer's lower boundary (*)

Report the distinctness of the layer's lower boundary.

Table 8.30: Distinctness of layer boundaries, Schoeneberger et al. (2012), 2-6, modified

Mineral layers, organotechnic layers and hydromorphic organic layers: transition within (cm)	Terrestrial organic layers: transition within (cm)	Distinctness	Code
≤ 0.5	≤ 0.1	Very Abrupt	V
> 0.5 - 2	> 0.1 - 0.2	Abrupt	A
> 2 - 5	> 0.2 - 0.5	Clear	C
> 5 - 15	> 0.5 - 1	Gradual	G
> 15	> 1	Diffuse	D

Shape

Report the shape. The characteristic refers to the layer's lower boundary or, if the shape is 'broken', to the entire layer.

Table 8.31: Shape of layer boundaries, Schoeneberger et al. (2012), 2-7

Criterion	Shape	Code
Nearly plane surface	Smooth	S
Pockets less deep than wide	Wavy	W
Pockets more deep than wide	Irregular	I
Discontinuous	Broken	B

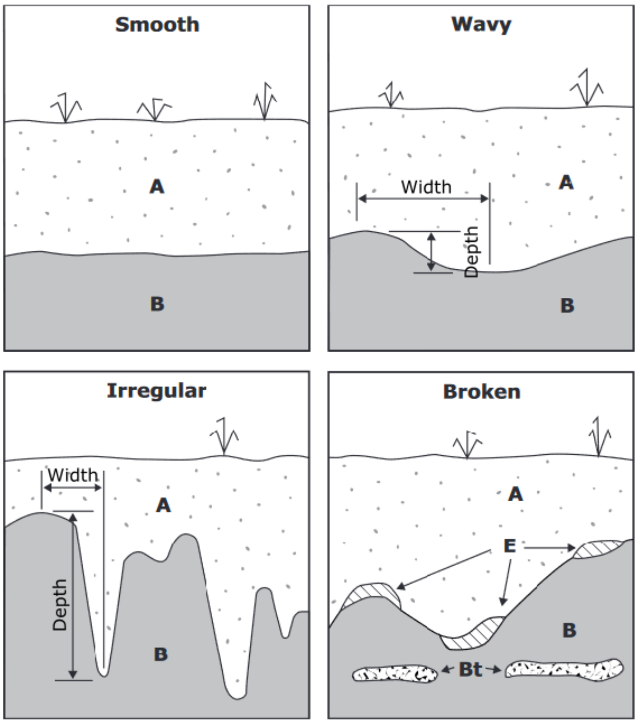


Figure 8.11: Shape of layer boundaries, Schoeneberger et al. (2012), 2-7, modified

8.4.6 Wind deposition (m)

Report any evidence of wind deposition. Use a hand lens (maximum 10x).

Table 8.32: Types of wind deposition

Criterion	Code
Aeroturbation (cross-bedding)	CB
≥ 10% of the particles of medium sand or coarser are rounded or subangular and have a matt surface	RH
≥ 10% of the particles of medium sand or coarser are rounded or subangular and have a matt surface, but only in in-blown material that has filled cracks	RC
Other	OT
No evidence of wind deposition	NO

8.4.7 Coarse fragments and remnants of broken-up cemented layers (o, m)

This Chapter refers to natural coarse fragments and to remnants of broken-up cemented layers. *Artefacts* are described in Chapter 8.4.8. A coarse fragment is a mineral particle, derived from the parent material, > 2 mm in its equivalent diameter (see Chapter 8.4.9). Remnants of broken-up cemented layers may be of any size but are only reported here if they have an equivalent diameter > 2 mm. The subdivisions (0.6 to 60 cm) are according to their greatest dimension.

Size and shape

The Table indicates the length of the greatest dimension and the shape.

Table 8.33: Size and shape classes of coarse fragments and of remnants of broken-up cemented layers, FAO (2006), Tables 27 and 28

Size (cm)		Size class	Shape	Code
> 0.2 - 0.6		Fine gravel	Rounded	FR
			Angular	FA
			Rounded and angular	FB
> 0.6 - 2		Medium gravel	Rounded	MR
			Angular	MA
			Rounded and angular	MB
> 2 - 6		Coarse gravel	Rounded	CR
			Angular	CA
			Rounded and angular	CB
> 6 - 20		Stones	Rounded	SR
			Angular	SA
			Rounded and angular	SB
> 20 - 60		Boulders	Rounded	BR
			Angular	BA
			Rounded and angular	BB
> 60		Large boulders	Rounded	LR
			Angular	LA
			Rounded and angular	LB
None				NO

Weathering stage (coarse fragments) and cementing agent (remnants of broken-up cemented layers)

Table 8.34: Weathering stage of coarse fragments, FAO (2006), Table 29

Criterion	Weathering stage	Code
No or little signs of weathering	Fresh	F
Loss of original rock colour and loss of crystal form in the outer parts; centres remain relatively fresh; original strength relatively well preserved	Moderately weathered	M
All but the most resistant minerals weathered; original rock colour lost throughout; tend to disintegrate under only moderate pressure	Strongly weathered	S

Table 8.35: Remnants of broken-up cemented layers: cementing agent

Cementing agent	Code
Secondary carbonates	CA
Secondary gypsum	GY
Secondary silica	SI
Fe oxides, predominantly inside (former) soil aggregates, no significant concentration of organic matter	FI
Fe oxides, predominantly on the surfaces of (former) soil aggregates, no significant concentration of organic matter	FO
Fe oxides, no relationship to (former) soil aggregates, no significant concentration of organic matter	FN
Fe oxides in the presence of a significant concentration of organic matter	FH

Abundance (by volume)

Report the total percentage of the volume occupied by coarse fragments. In addition, report at least one and up to four size and shape classes and report their weathering stage and the percentage of the volume that is occupied by the coarse fragments of the respective class, the dominant one first. Report the total percentage of the volume occupied by remnants of broken-up cemented layers, report the agent that caused the cementation, where applicable up to two, and the percentage of the volume that is occupied by the remnants of each cementation, the dominant one first (see Chapters 8.4.30 and 8.4.32). All volumes are related to the whole soil. Figure 8.12 helps with the estimation of the volume.

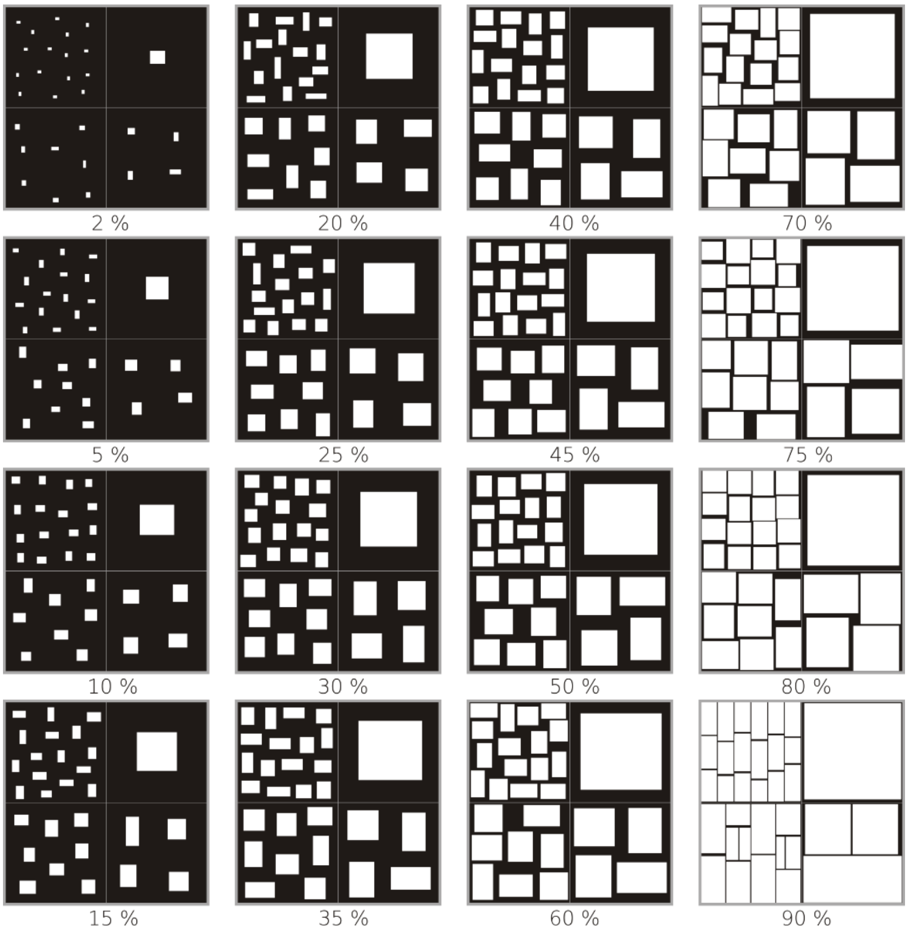


Figure 8.12: Charts for estimating percentages of coarse fragments and of remnants of broken-up cemented layers, FAO (2006), Figure 5, modified by B. Repe

Free large pores (interstices) between coarse fragments

Between coarse fragments, large pores may exist that are visible with the naked eye and do not contain soil material. Report the total percentage (by volume, related to the whole soil).

8.4.8 Artefacts (o, m)

Artefacts are solid or liquid substances that are

- created or substantially modified by humans as part of an industrial or artisanal manufacturing process, or
- brought to the surface by human activity from a depth, where they were not influenced by surface processes, and deposited in an environment, where they do not commonly occur.

Type

Table 8.36: Examples of artefacts, Schoeneberger et al. (2012), 2-50, modified

Type	Code
Bitumen (asphalt), continuous	BT
Bitumen (asphalt), fragments	BF
Black carbon (e.g. charcoal, partly charred particles, soot)	BC
Boiler slag	BS
Bottom ash	BA
Bricks, adobes	BR
Ceramics	CE
Cloth, carpet	CL
Coal combustion byproducts	CU
Concrete, continuous	CR
Concrete, fragments	CF
Crude oil	CO
Debitage (stone tool flakes)	DE
Dressed or crushed stones	DS
Fly ash	FA
Geomembrane, continuous	GM
Geomembrane, fragments	GF
Glass	GL
Gold coins	GC
Household waste (undifferentiated)	HW
Industrial waste	IW
Lumps of applied lime	LL
Metal	ME
Mine spoil	MS
Organic waste	OW
Paper, cardboard	PA
Plasterboard	PB
Plastic	PT
Processed oil products	PO
Rubber (tires etc.)	RU
Treated wood	TW
Other	OT
None	NO

Note: If not purposefully made by humans, black carbon is considered to be natural (see Chapter 8.4.36).

Size

The Table indicates the average length of the greatest dimension of solid *artefacts*.

Table 8.37: Size of artefacts, FAO (2006), Table 27

Size (cm)	Size class	Code
≤ 0.2	Fine earth	E
> 0.2 - 0.6	Fine gravel	F
> 0.6 - 2	Medium gravel	M
> 2 - 6	Coarse gravel	C
> 6 - 20	Stones	S
> 20 - 60	Boulders	B
> 60	Large boulders	L

Abundance (by volume)

Report the total percentage of the volume (related to the whole soil) occupied by solid *artefacts*. In addition, report at least one and up to five types and size classes and the percentage of the volume that is occupied by the respective type and size class, the dominant one first. Figure 8.12 helps with the estimation of the volume. Black carbon has to be additionally reported as percentage of the exposed area (related to the fine earth plus black carbon of any size).

8.4.9 Soil texture (m) (*)

Particle-size classes

Table 8.38: Particle-size classes, ISO 11277:2009

Particle-size class	Diameter of particles
Fine earth	all particles ≤ 2 mm
Sand	> 63 µm - ≤ 2 mm
Very coarse sand	> 1250 µm - ≤ 2 mm
Coarse sand	> 630 µm - ≤ 1250 µm
Medium sand	> 200 µm - ≤ 630 µm
Fine sand	> 125 µm - ≤ 200 µm
Very fine sand	> 63 µm - < 125 µm
Silt	> 2 µm - ≤ 63 µm
Clay	≤ 2 µm

The particle size classes up to 2 mm are defined according to the equivalent diameter. The equivalent diameter is the diameter of a sphere that in sedimentation analysis sinks with the same velocity as the respective particle.

The human eye and the tactile sense of the fingers can detect particles > 150 - 300 µm, depending on individual sensitivity.

Texture classes

Report the texture class. Please note that the hand-texturing according to the following flow chart only provides an estimation of the texture. Especially around the limits between the classes, the results might be not absolutely reliable. Beginners should ask experienced soil scientists for help.

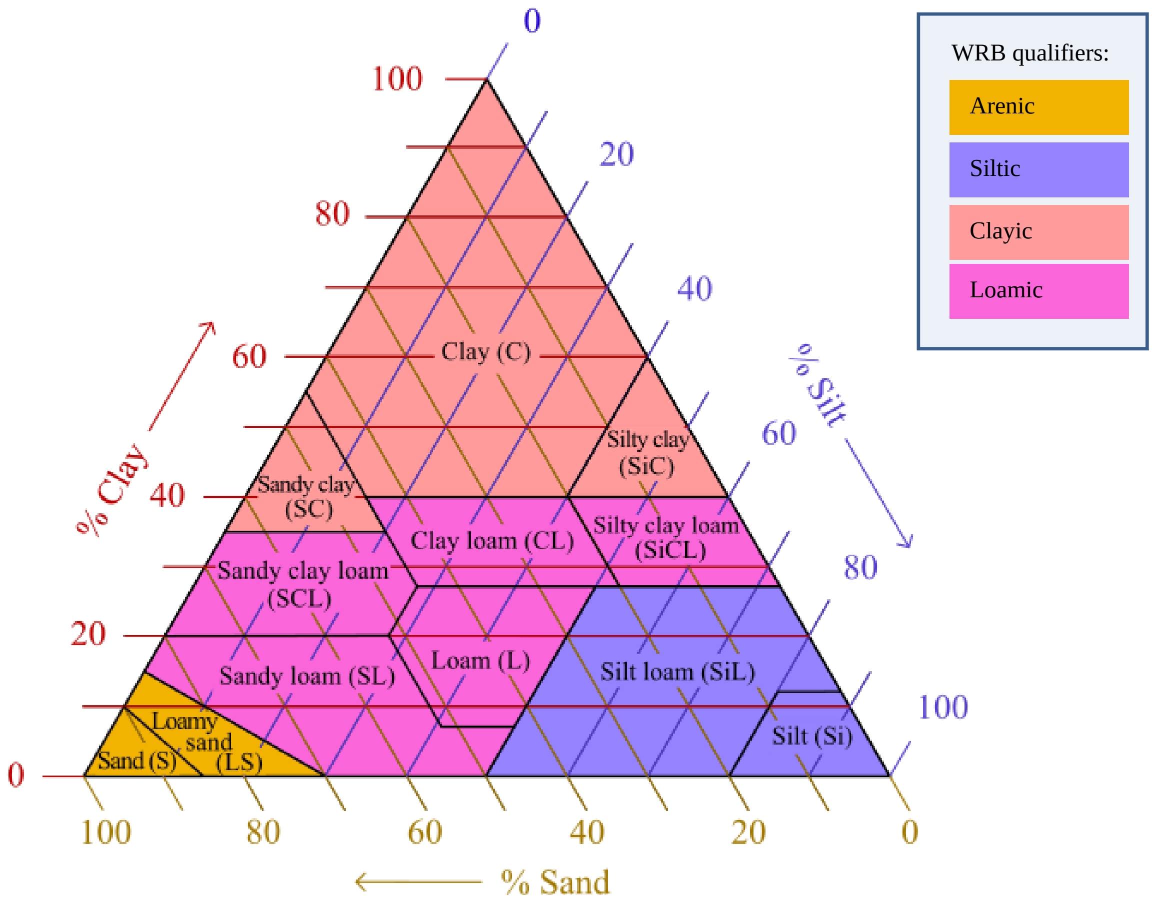


Figure 8.13: Texture classes, triangle, Blum et al. (2018), Figure 28, modified

Table 8.39: Texture classes, Soil Science Division Staff (2017)

Texture class	% sand	% silt	% clay	Additional criteria
Sand (S)	> 85	< 15	< 10	(%silt + 1.5×%clay) < 15
Loamy sand (LS)	> 70 to ≤ 90	< 30	< 15	(%silt + 1.5×%clay) ≥ 15 and (%silt + 2×%clay) < 30
Silt (Si)	≤ 20	≥ 80	< 12	
Silt loam (SiL)	≤ 50	≥ 50 to < 80	< 27	
	≤ 8	≥ 80 to ≤ 88	≥ 12 to ≤ 20	
Sandy loam (SL)	> 52 to ≤ 85	≤ 48	< 20	(%silt + 2×%clay) ≥ 30
	> 43 to ≤ 52	≥ 41 to < 50	< 7	
Loam (L)	> 23 to ≤ 52	≥ 28 to < 50	≥ 7 to < 27	
Sandy clay loam (SCL)	> 45 to ≤ 80	< 28	≥ 20 to < 35	
Silty clay loam (SiCL)	≤ 20	> 40 to ≤ 73	≥ 27 to < 40	
Clay loam (CL)	> 20 to ≤ 45	> 15 to < 53	≥ 27 to < 40	
Sandy clay (SC)	> 45 to ≤ 65	< 20	≥ 35 to < 55	
Silty clay (SiC)	≤ 20	≥ 40 to ≤ 60	≥ 40 to ≤ 60	
Clay (C)	≤ 45	< 40	≥ 40	

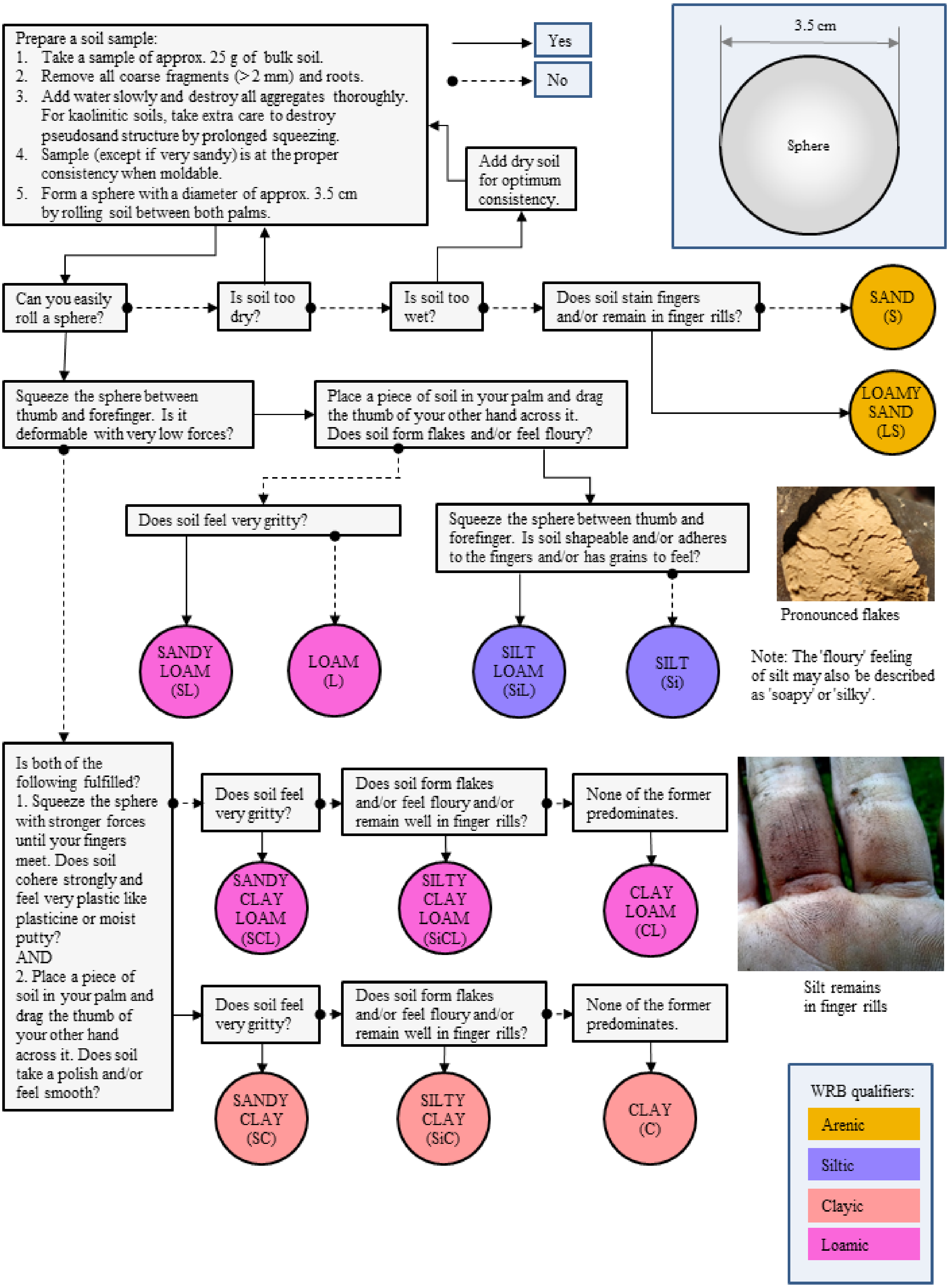


Figure 8.14: Texture classes, flow chart, ideas adapted from
- Natural England Technical Information Note TIN037 (2008)
- Thien (1979)

Subclasses of the texture classes sand and loamy sand

If the layer belongs to the texture classes sand or loamy sand, report the subclass. The particle-size subclasses of sand are detected by visual estimation of the diameters of the grains or by laboratory analysis. The texture subclasses very fine sand and loamy very fine sand tend to feel floury, whereas all the coarser subclasses feel grainy.

Table 8.40: Subclasses of the texture classes sand and loamy sand, Soil Science Division Staff (2017), modified; the percentages of the sand fractions are related to the entire fine earth (not related to sand).

% very coarse and coarse sand	% medium sand	% sum of very coarse, coarse and medium sand	% fine sand	% very fine sand	Feel	Subclasses of the texture class sand	Subclasses of the texture class loamy sand
≥ 25	< 50	Not defined	< 50	< 50	Grainy	Coarse sand (CS)	Loamy coarse sand (LCS)
< 25	Not defined	≥ 25	< 50	< 50	Grainy	Medium sand (MS)	Loamy medium sand (LMS)
≥ 25	≥ 50	Not defined	Not defined	Not defined			
Not defined	Not defined	Not defined	≥ 50	Not defined	Grainy	Fine sand (FS)	Loamy fine sand (LFS)
Not defined	Not defined	< 25	Not defined	< 50			
Not defined	Not defined	Not defined	Not defined	≥ 50	Tending to be floury	Very fine sand (VFS)	Loamy very fine sand (LVFS)

8.4.10 Structure (m)

Structure is the spatial arrangement of soil constituents and pores. If this is, at least partially, the result of soil-forming processes, it is called **soil structure**. Otherwise, it is **rock structure**. Structure refers to the fine earth. Structure is reported for mineral layers. Additionally, structure is reported for drained hydromorphic organic layers.

A **soil aggregate** is a discrete structural body that can be clearly distinguished from its surroundings and that results from soil-forming processes. If a force is applied to a specimen, and the specimen breaks along natural surfaces of weakness, it is composed of aggregates. If the specimen breaks exactly where force is applied, the structure is **massive** (coherent). If there is no coherence between the particles, the structure is of **single-grain** type. Human disturbance may create artificial structural elements, which are called **clods**.

Undisturbed aggregates or non-aggregated structure are called the first-level structure. Aggregates of the types subangular blocky, angular blocky, polyhedral, lenticular, platy, wedge-shaped, prismatic, and columnar may break into aggregates of a second-level structure and even further into aggregates of a third-level structure. The second-level and the third-level structure may be of the same type(s) as the first-level structure or of a different one.

Use the spade, take out a large sample, make sure that the aggregates of the first-level structure, if present, are undisturbed, and observe the structure. Report the type, if present, up to three, the dominant one first. For each type, report separately grade, penetrability for roots, and size class. If applicable, report two size classes, the dominant one first. Report for every type and size class the abundance (as percentage by volume of the layer).

From the first-level structure, take some specimens from each type (if more than one size class of a type is present, take only the greater one) and try to break them with low forces. If aggregates of a second-level structure appear, report the type, if present, up to two, the dominant one first. For each type, report separately grade, size class, and penetrability for roots. If applicable, report two size classes, the dominant one first. Report for every type and size class the abundance (as percentage by volume of the respective first level structure).

From the second-level structure, take some specimens from each type (if more than one size class of a type is present, take only the greater one) and try to break them with low forces. If aggregates of a third-level structure appear, report type, grade, size class, and penetrability for roots. If applicable, report two size classes, the dominant one first. Report for every size class the abundance (as percentage by volume of the respective second level structure).

Types

Figure 8.15 explains some general terms of soil aggregate description.

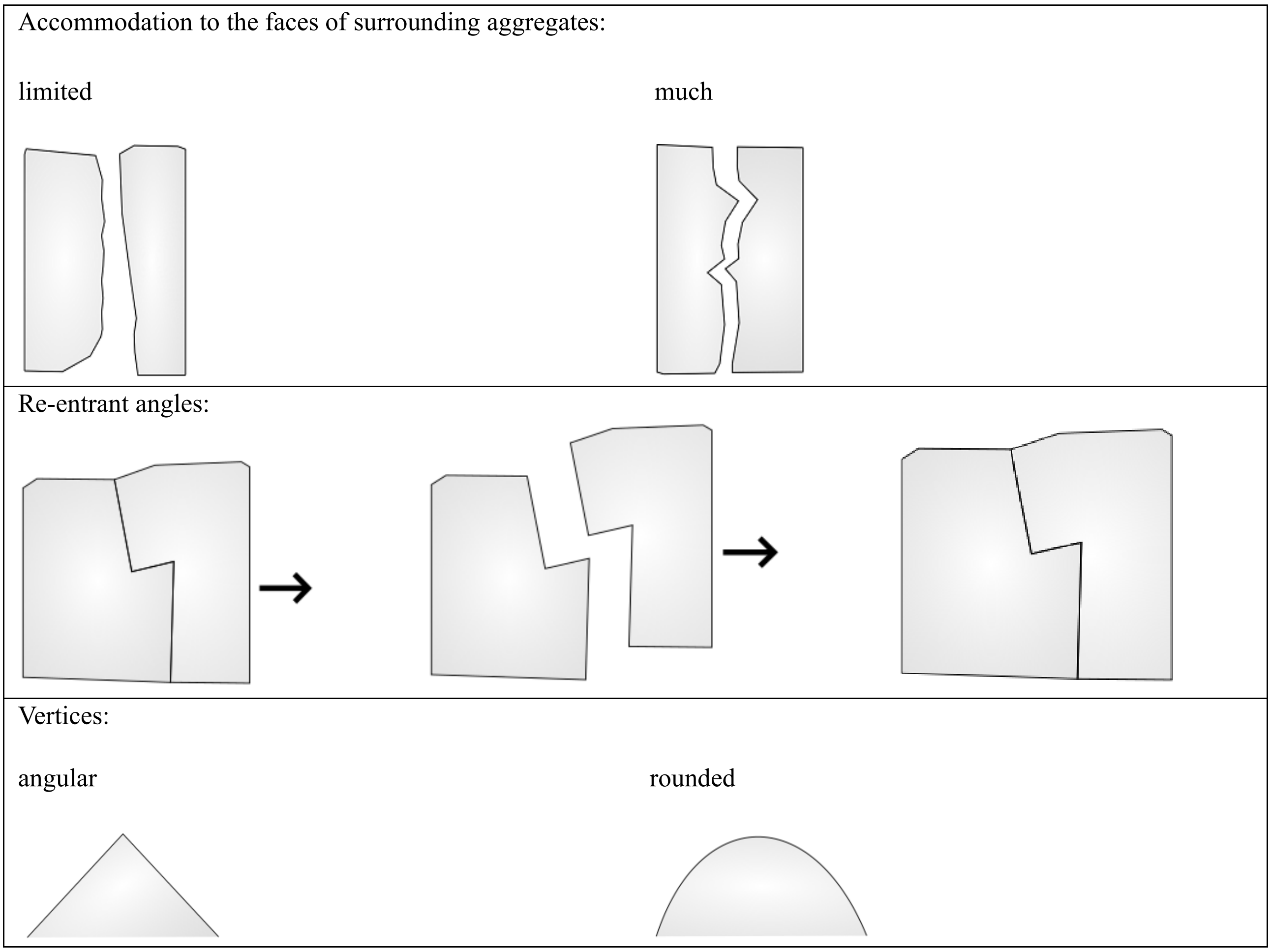
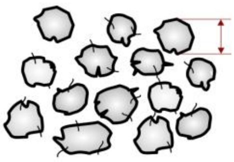
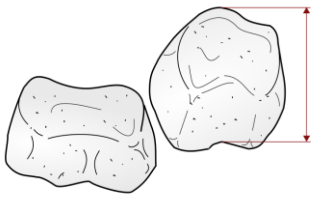
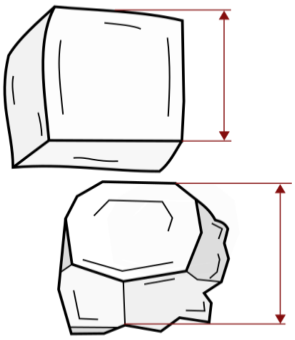
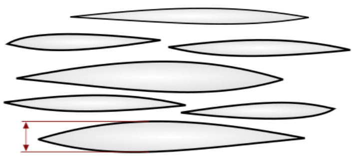
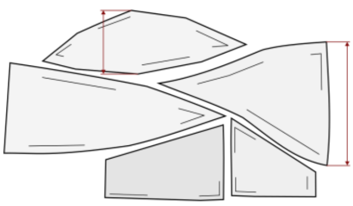
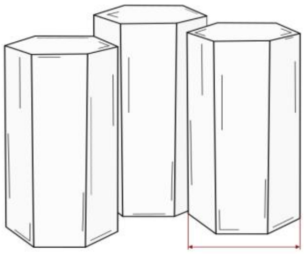
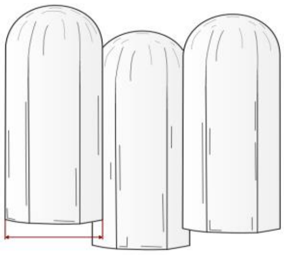
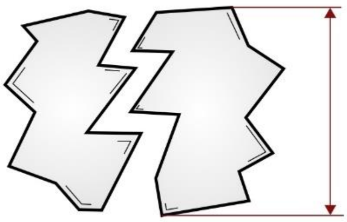
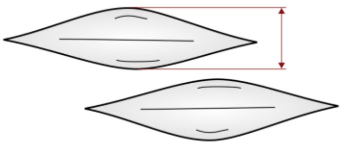
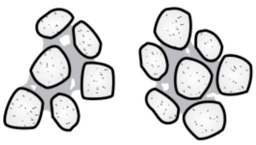
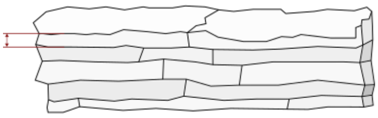


Figure 8.15: General terms of soil aggregate description

Table 8.41: Types of structure, descriptions, Schoeneberger et al. (2012), 2-53, FAO (2006), Table 49, National Committee on Soil and Terrain (2009), 171-181, modified

Granular 	Spheroidal; biogenic; many visible pores; bounded by curved or very irregular faces; limited accommodation to the faces of surrounding aggregates
Subangular blocky 	Bounded by undulating rough faces; number of faces variable; many vertices rounded; limited accommodation to the faces of surrounding aggregates
Angular blocky 	Bounded by relatively flat smooth, roughly equal faces; number of faces variable; most vertices angular; usually much accommodation to the faces of surrounding aggregates
Lenticular 	Bounded by curved faces; overlapping, lens-shaped aggregates generally parallel to the soil surface that are thick at the centre and taper toward the edges; usually much accommodation to the faces of surrounding aggregates; (formed by active or relict frost processes)
Wedge-shaped 	Bounded by flat faces; interlocking wedges or lenses that terminate in pronounced angular vertices; ends of vertices may be missing; much accommodation to the faces of surrounding aggregates (typical for first-level or second-level structure in *vertic horizons*)

Prismatic 	Bounded by relatively flat faces; vertically elongated units with angular vertices and flat tops; much accommodation to the faces of surrounding aggregates
Columnar 	Bounded by relatively flat faces; vertically elongated units with angular to rounded vertices and rounded (domed) tops
Polyhedral 	Bounded by relatively flat smooth, unequal faces; more than six faces; most vertices angular; usually much accommodation to the faces of surrounding aggregates; re-entrant angles between adjoining faces (typical for second-level structure in *nitic horizons*)
Flat-edged 	Bounded by curved faces; lens-shaped aggregates that are thick at the centre and taper toward the edges; limited accommodation to the faces of surrounding aggregates (typical for second-level structure in *nitic horizons*)
Pseudosand/ Pseudosilt 	Spheroidal units of sand and silt size, composed of kaolinite-oxide complexes; the complexes may be interconnected to each other; hand-texturing according to Chapter 8.4.9 first yields the impression of a dominance of sand and silt and after prolonged squeezing proves the dominance of clay
Platy 	Bounded by relatively flat horizontal faces; much accommodation to the faces of surrounding aggregates

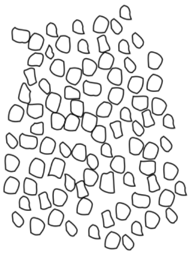
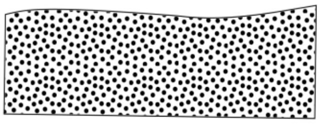
Single grain 	Entirely non-coherent, e.g., loose sand
Massive 	Material is a coherent mass (not necessarily cemented)
Cloddy 	Artificial clods created by disturbance; e.g., ploughing

Table 8.42: Types of structure, formation and codes

Type	Formation	Code
Granular	Soil aggregate structure, natural	GR
Subangular blocky	Soil aggregate structure, natural	BS
Angular blocky	Soil aggregate structure, natural	BA
Lenticular	Soil aggregate structure, natural	LC
Wedge-shaped	Soil aggregate structure, natural	WE
Prismatic	Soil aggregate structure, natural	PR
Columnar	Soil aggregate structure, natural	CO
Polyhedral	Soil aggregate structure, natural	PH
Flat-edged	Soil aggregate structure, natural	FE
Pseudosand/Pseudosilt	Soil aggregate structure, natural	PS
Platy	Soil aggregate structure, natural or resulting from artificial pressure	PL
Single grain	No structural units, rock structure, inherited from the parent material	SR
	No structural units, soil structure, resulting from soil-forming processes, like loss of organic matter and/or oxides and/or clay minerals or loss of stratification	SS
Massive	No structural units, rock structure, inherited from the parent material, structure not changing with soil moisture, not or only slightly chemically weathered	MR
	No structural units, rock structure, inherited from the parent material, structure not changing with soil moisture, strongly chemically weathered (e.g. saprolite)	MW
	No structural units, soil structure, present when moist and changing into soil aggregate structure when dry	MS
Stratified	No structural units, rock structure, visible stratification from sedimentation	ST
Cloddy	Artificial structural elements	CL

Grade

Table 8.43: Grade of structural units, Soil Science Division Staff (2017), 159f, modified

Criterion	Grade	Code
The units are barely observable in place. When gently disturbed, the soil material parts into a mixture of whole and broken units, the majority of which exhibit no surfaces of weakness. The surfaces differ in some way from the interiors.	Weak	W
The units are well formed and evident in place. When disturbed, the soil material parts into a mixture of mostly whole units, some broken units, and material that is not in units. Aggregates part from adjoining aggregates to reveal nearly entire faces that have properties distinct from those of fractured surfaces.	Moderate	M
The units are distinct in place. When disturbed, they separate cleanly, mainly into whole units. Aggregates have distinct surface properties.	Strong	S

Penetrability for roots

Large soil aggregates may have a dense outer rim that does not allow roots to enter.

Table 8.44: Aggregate penetrability for roots

Criterion	Code
All aggregates with dense outer rim	P
Some aggregates with dense outer rim	S
No aggregate with dense outer rim	N

Size

The dimension to be reported is indicated in Table 8.41 by a line.

Table 8.45: Aggregate size, Schoeneberger et al. (2012), 2-55, FAO (2006), Table 50, modified

Criterion: size of structural unit (mm)			Size class	Code
Granular, Flat-edged, Platy	Subangular blocky, Angular blocky, Lenticular, Polyhedral, Cloddy	Wedge-shaped, Prismatic, Columnar		
≤ 1	≤ 5	≤ 10	Very fine	VF
> 1 - 2	> 5 - 10	> 10 - 20	Fine	FI
> 2 - 5	> 10 - 20	> 20 - 50	Medium	ME
> 5 - 10	> 20 - 50	> 50 - 100	Coarse	CO
> 10 - 20	> 50 - 100	> 100 - 300	Very coarse	VC
> 20	> 100	> 300	Extremely coarse	EC

Inclination of wedge-shaped aggregates

If wedge-shaped aggregates are present, report the volume (as percentage), occupied by wedge-shaped aggregates tilted between ≥ 10° and ≤ 60° from the horizontal.

8.4.11 Pores and cracks (overview)

Soil has air- or water-filled voids, which are:

- Interstitial (primary packing voids)
- Non-matrix pores (tubular, dendritic tubular, vesicular, irregular)
- Interstructural (fractures between soil aggregates, which can be inferred from soil structure description)
- Cracks (fissures other than those attributed to soil structure).

We only report non-matrix pores and cracks.

8.4.12 Non-matrix pores (m)

Type

Table 8.46: Types of non-matrix pores, Schoeneberger et al. (2012), 2-73, modified

Criterion	Type	Code
Cylindrical and elongated voids; e.g., worm tunnels	Tubular	TU
Cylindrical, elongated, branching voids; e.g., empty root channels	Dendritic Tubular	DT
Ovoid to spherical voids; e.g., solidified pseudomorphs of entrapped gas bubbles concentrated below a crust; most common in arid and semiarid environments and in permafrost soils	Vesicular	VE
Non-connected cavities, chambers; e.g., vughs; various shapes	Irregular	IG
No non-matrix pores		NO

Tubular and dendritic tubular pores are commonly referred to as **biopores**.

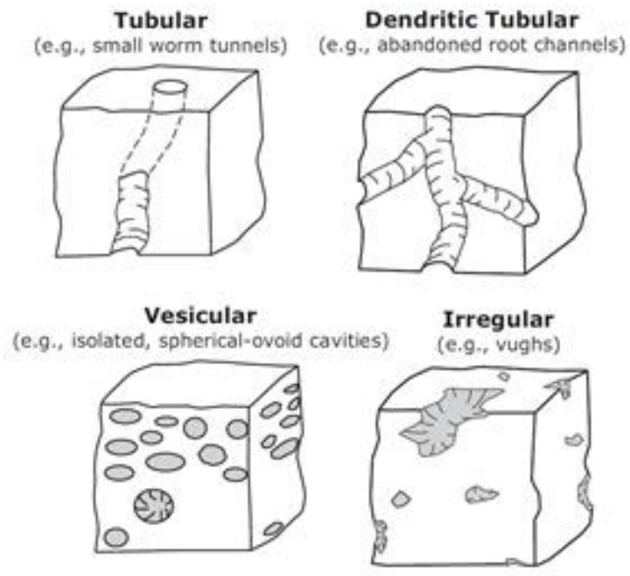


Figure 8.16: Type of non-matrix pores, Schoeneberger et al. (2012), 2-74

Size and abundance

Table 8.47: Pore size, Schoeneberger et al. (2012), 2-70

Diameter	Soil area to be assessed	Size class	Code
≤ 1 mm	1 cm^2	Very Fine	VF
> 1 - 2 mm	1 cm^2	Fine	FI
> 2 - 5 mm	1 dm^2	Medium	ME
> 5 - 10 mm	1 dm^2	Coarse	CO
> 10 mm	1 m^2	Very Coarse	VC

Table 8.48: Abundance of pores, Schoeneberger et al. (2012), 2-70, modified

Number	Abundance class	Code
≤ 1	Very Few	V
> 1 - 3	Few	F
> 3 - 5	Common	C
> 5	Many	M

Report all non-matrix pore types that apply. For every type and every size class, count the number of pores in

the assessed area. For every type, report the dominant size class (size class that has the highest number of pores). For every type, calculate the sum of pores across the size classes and report the abundance class.
Example:
Very fine: 0
Fine: 2
Medium: 2
Coarse: 1
Very coarse: 0
The sum is 5, and the abundance class is Common.

8.4.13 Cracks (o, m)

Report persistence and continuity,

Persistence

Table 8.49: Persistence of cracks, Schoeneberger et al. (2012), 2-76

Criterion	Code
Reversible (open and close with changing soil moisture)	RT
Irreversible (persist year-round)	IT
No cracks	NO

Continuity

Table 8.50: Continuity of cracks

Criterion	Code
All cracks continue into the underlying layer	AC
At least half, but not all of the cracks continue into the underlying layer	HC
At least one, but less than half of the cracks continue into the underlying layer	SC
Cracks do not continue into the underlying layer	NC

Width and abundance

Report the average width in mm and the number of cracks. Count the cracks across 1 m horizontally; use the vertical centre of the layer.

8.4.14 Stress features (m)

Stress features result from soil aggregates that are pressed against each other due to swelling clays. The aggregate surfaces may be shiny. There are two types: Pressure faces do not slide past each other and have no striations, slickensides slide past each other and have striations. Striations develop if sand (or silt) grains are moved with strong pressure along the aggregate surfaces. Stress features do not differ in colour from the matrix (see Chapter 8.4.17). A hand lens (maximum 10x) may be helpful. Report the abundance of

- Pressure faces in % of the surfaces of soil aggregates
- Slickensides in % of the surfaces of soil aggregates.

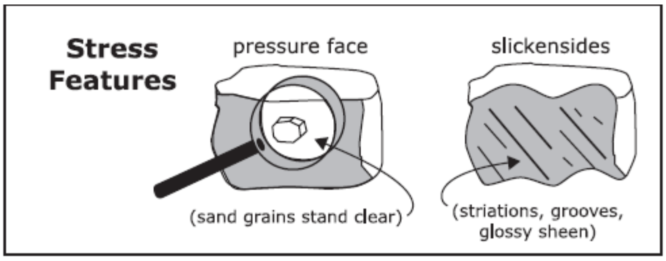


Figure 8.17: Type of stress features, Schoeneberger et al. (2012), 2-34

8.4.15 Concentrations (overview)

The following definitions apply to concentrations, e.g., redox concentrations or secondary carbonates (some concentrations may not show all the below-listed types). For cementation classes, see Chapter 8.4.30.

Table 8.51: Types of concentrations (overview), Soil Science Division Staff. (2017), page 174f

Description	Designation
Rounded body, at least very weakly cemented, that can be removed as discrete unit, with internal organization in the form of concentric layers that are visible to the naked eye	Concretion
Rounded body, at least very weakly cemented, that can be removed as discrete unit, without evident internal organization	Nodule
Longitudinal body of any cementation class	Filament
Non-cemented or extremely weakly cemented body, of various shape, that cannot be removed as discrete unit	Mass

8.4.16 Soil colour (overview)

In general, soil colour can be a property of the four following soil features:

- Matrix (see Chapter 8.4.17 and Chapter 8.4.18)
- Lithogenic variegates (see Chapter 8.4.19)
- Redoximorphic features, resulting from redox processes (see Chapter 8.4.20)
- Non-redoximorphic features, resulting from other pedogenic processes:
  - initial weathering (see Chapter 8.4.22)
  - clay coatings and bridges (see Chapter 8.4.23)
  - uncoated sand and/or coarse silt grains (see Chapter 8.4.23)
  - ribbon-like accumulations (see Chapter 8.4.24)
  - secondary carbonates (see Chapter 8.4.25)
  - secondary gypsum (see Chapter 8.4.26)
  - secondary silica (see Chapter 8.4.27)
  - readily soluble salts (see Chapter 8.4.28)
  - accumulations of organic matter (see Chapter 8.4.36)

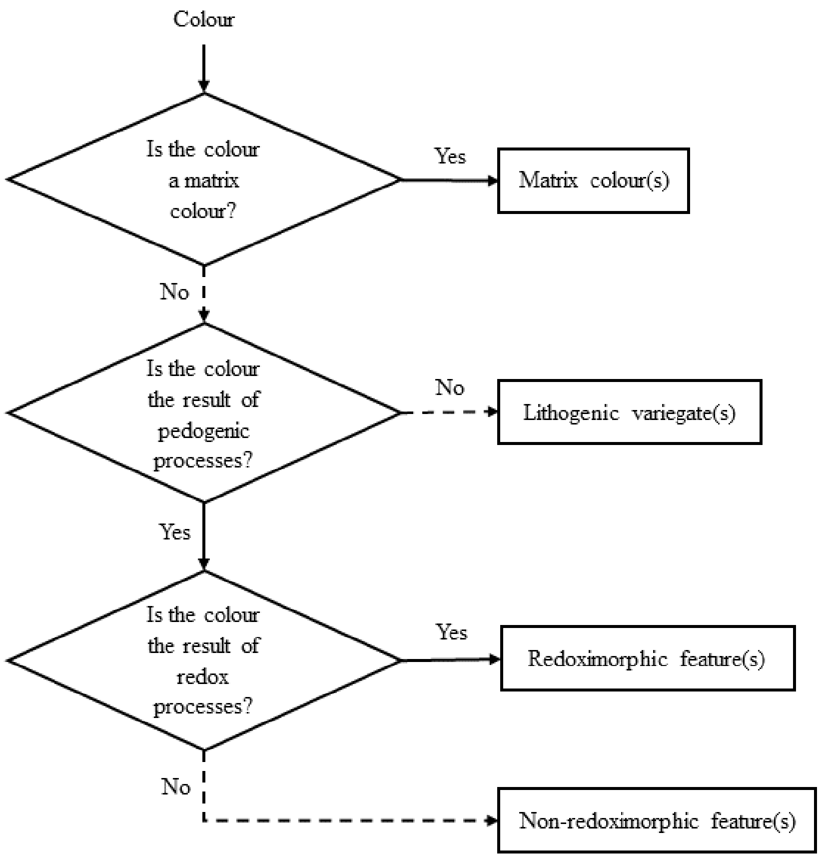


Figure 8.18: Colour flow chart, Schoeneberger et al. (2012), 2-8, modified

Use the Munsell Color Charts. Take a fresh sample, slightly crush it and observe the colour in the shade (both your eyes and the colour chart in the shade) and not in the twilight. Report hue, value and chroma. The matrix colour and the colour of reductimorphic features are recorded twice, moist and (if possible) dry, the other colours only in the moist state. The moist state corresponds to field capacity, which is obtained with sufficient accuracy by moistening and reading the colour as soon as visible moisture films have disappeared.

8.4.17 Matrix colour (m) (*)

Report the colour of the soil matrix. If there is more than one matrix colour, report up to three, the dominant one first, and give the percentage of the exposed area.

Advanced chemical weathering without physical alteration, especially without turbation, results in saprolite (see Chapter 8.4.10). According to the minerals present, a colour pattern may result. These colours are reported as matrix colours.

8.4.18 Combinations of darker-coloured finer-textured and lighter-coloured coarser-textured parts (m)

If a layer consists of darker-coloured finer-textured and lighter-coloured coarser-textured parts that do not form horizontal layers but can easily be distinguished, describe them separately. Use separate lines in the Soil Description Sheet (Annex 4, Chapter 11) and give a full description. The principal colours are regarded to be matrix colours.

For the coarser-textured parts, report in addition the following characteristics:

- the percentage (by exposed area) occupied by coarser-textured parts of any orientation (vertical, horizontal, inclined) having a width of ≥ 0.5 cm
- the percentage (by exposed area) occupied by continuous vertical tongues of coarser-textured parts with a horizontal extension of ≥ 1 cm (if these tongues are absent, report 0%)
- the depth range in cm, where these tongues cover ≥ 10% of the exposed area (if they extend across several layers, the length is only reported in the description of that layer, where they start at the layer's upper limit).

In the middle of the layer, prepare a horizontal surface, 50 cm x 50 cm, and report the percentage (by horizontal area covered) of the coarser-textured parts.

8.4.19 Lithogenic variegates (m)

Report colour, size class, and abundance. If more than one colour occurs, report up to three, the dominant one first, and give size class and abundance for each colour separately.

Colour

Report the colour according to the Munsell Color Charts. Write 'None' if there are no lithogenic variegates.

Size

The Table indicates the average length of the greatest dimension.

Table 8.52: Size of lithogenic variegates, FAO (2006), Table 33

Size (mm)	Size class	Code
≤ 2	Very fine	V
> 2 - 6	Fine	F
> 6 - 20	Medium	M
> 20	Coarse	C

Abundance (by exposed area)

Report the percentage of abundance.

8.4.20 Redoximorphic features (m)

Redoximorphic features (oximorphic features plus reductimorphic features) are the result of redox processes. Oximorphic features show the accumulation of substances in oxidized state and usually a redder hue, a higher chroma and a lower value than the surrounding material, while reductimorphic features show the opposite characteristics. Soil parts showing reductimorphic features may either contain substances in reduced state or may have lost them.

Report substance, location, size class (up to two, the dominant one first), cementation class and abundance for each colour separately, for up to three colours, the dominant one first. Substance for oximorphic features is always reported, for reductimorphic features only in some cases. Size class is only reported for oximorphic features inside soil aggregates. Cementation is only reported for oximorphic features. The abundance is reported as percentage of the exposed area.

Colour (*)

Report the colour according to the Munsell Color Charts. Write 'None' if there are no redoximorphic features.

Substance (*)

Table 8.53: Substance of oximorphic features

Substance	Code
Fe oxides	FE
Mn oxides	MN
Fe and Mn oxides	FM
Jarosite	JA
Schwertmannite	SM
Fe and Al sulfates (not specified)	AS

The term 'oxides', as used here, includes hydroxides and oxide-hydroxides. The term 'sulfates' includes hydroxysulfates.

Table 8.54: Substance of reductimorphic features

Substance	Code
Fe sulfides	FS
No visible accumulation	NV

Location (*)

Table 8.55: Location of oximorphic features

Location		Code
Inner parts	Inside soil aggregates: masses	OIM
	Inside soil aggregates: concretions	OIC
	Inside soil aggregates: nodules	OIN
	Inside soil aggregates: both concretions and/or nodules (not possible to distinguish)	OIB
Outer parts	On surfaces of soil aggregates	OOA
	Adjacent to surfaces of soil aggregates, infused into the matrix (hypocoats)	OOH
	On biopore walls, lining the entire wall surface	OOE
	On biopore walls, not lining the entire wall surface	OON
	Adjacent to biopores, infused into the matrix (hypocoats)	OOI
Random (not associated with aggregate surfaces or pores)	Distributed over the layer, no order visible	ORN
	Distributed over the layer, surrounding areas with reductimorphic features	ORS
	Throughout	ORT

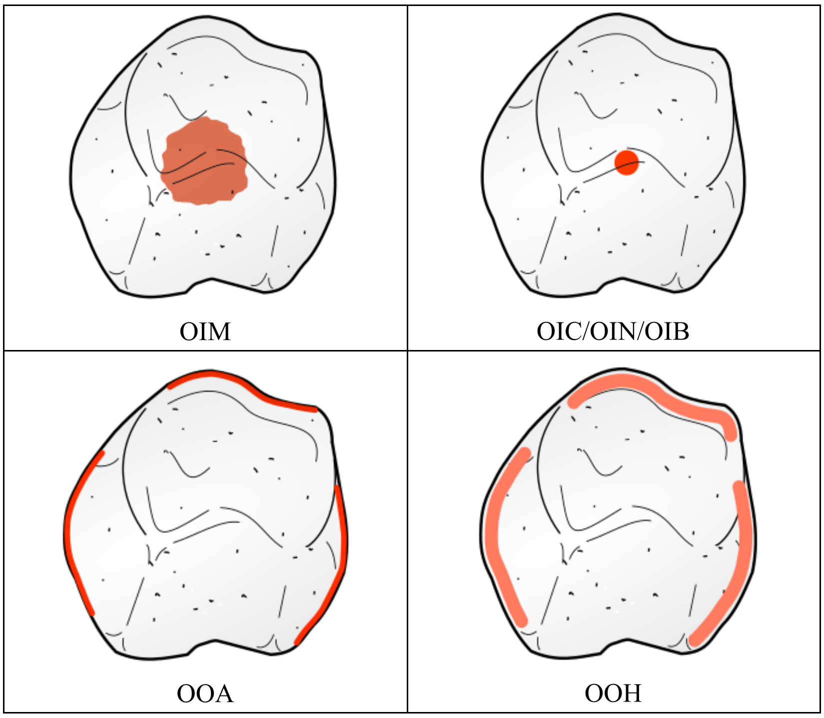


Figure 8.19: Location of some oximorphic features

Table 8.56: Location of reductimorphic features

Location		Code
Inner parts	Inside soil aggregates	RIA
Outer parts	Outer parts of soil aggregates	ROA
	Around biopores, surrounding the entire pores	ROE
	Around biopores, not surrounding the entire pores	RON
Random (not associated with aggregate surfaces or pores)	Distributed over the layer, no order visible	RRN
	Distributed over the layer, surrounding areas with oximorphic features	RRS
	Throughout	RRT

Size of oximorphic features (*)

The Table indicates the average length of the greatest dimension.

Table 8.57: Size of oximorphic features, FAO (2006), Table 33

Size (mm)	Size class	Code
≤ 2	Very fine	VF
> 2 - 6	Fine	FI
> 6 - 20	Medium	ME
> 20 -60	Coarse	CO
> 60	Very coarse	VC

Cementation class of oximorphic features (*)

If an intact specimen is not obtainable, the oximorphic feature is not cemented. Otherwise, take out the feature, apply force perpendicular to its greatest dimension, observe the force needed for failure and report the cementation class.

Table 8.58: Consistence of oximorphic features, Schoeneberger et al. (2012), 2-63

Criterion	Class	Code
Intact specimen not obtainable or very slight force between fingers, < 8 N	Not cemented	NC
Slight force between fingers, 8 - < 20 N	Extremely weakly cemented	EWC
Moderate force between fingers, 20 - < 40 N	Very weakly cemented	VWC
Strong force between fingers, 40 - < 80 N	Weakly cemented	WEC
Does not fail when applying force between fingers, ≥ 80 N	Moderately or more cemented	MOC

Abundance (by exposed area)

Report the total abundance of the parts with oximorphic features and the total abundance of the parts with reductimorphic features, both for inner, outer and random locations, separately. Report them as percentage of the exposed area (related to the fine earth plus oximorphic features of any size and any cementation class).

Abundance of cemented oximorphic features (by volume)

This paragraph refers to cemented oximorphic features with a cementation class of at least moderately cemented and a diameter of > 2 mm. They comprise concretions and nodules (see above) and remnants of a broken-up layer that has been cemented by Fe oxides. Report the abundance as percentage by volume (related to the whole soil).

8.4.21 Redox potential and reducing conditions (o, m)

The soil redox potential (Eh) expresses the ratio of the concentrations of oxidized and reduced substances and is measured in millivolts (mV). In soils, redox potentials range from +800 mV to –350 mV. A low redox potential indicates strong reducing conditions. When opening a profile pit, oxygen gets access to the profile wall, which leads to a rapid oxidation of the exposed reduced substances and to a subsequent change of the redox potential at the profile wall.

Measure the redox potential and calculate the rH value

For measuring the redox potential (Blume et al., 2011; FAO, 2006), the following equipment is needed:

- a pointed stainless-steel rod of 4-5 mm in diameter, long enough to reach the desired soil depth
- a perforated plastic tube of 15-20 mm in diameter and of a length corresponding to the depth of measurement
- concentrated KCl solution, fixed with agar
- a Pt electrode
- a reference electrode, e.g., with Ag/AgCl in 1 M KCl or with calomel (as used for measuring the pH value)
- a potentiometer.

Procedure: Step 1 - 2 m aside the profile pit and drive the rod into the soil down to the desired depth, roughen the Pt electrode with fine-grained sandpaper, intrude it immediately into the hole and press it against the soil. Make another hole at 10-20 cm distance, wide and deep enough to place a plastic tube that is some cm longer than the depth of the Pt electrode. Fill the tube with the fixed KCl solution, place the tube into the hole and fix it with soil material. Then, place the reference electrode into the KCl solution. Connect the electrodes with the potentiometer and read the voltage after 30 minutes. Repeat readings every 10 minutes until the value is stable. In some cases, this may take several hours. At least two replicates are recommended. (If you dispose of more than one set of equipment, you may measure the redox potential simultaneously at

different soil depths.) The obtained voltage has to be adjusted to the voltage of the standard hydrogen electrode: for Ag/AgCl in 1 M KCl add +244 mV, for calomel add +287 mV. Simultaneously, measure the pH value (see Chapter 8.4.29) of the soil at the profile wall in distilled water (soil:water = 1:5) at the same depth. Report the rH value that is calculated with the following equation:
$rH = (2\ Eh/59) + 2\ pH$

Note: If the profile is freshly dug and not too sandy, you may also place the electrodes horizontally at least 15 cm behind in the profile wall.

Estimate the rH value (*)

The following field tests are available to prove reducing conditions:

- Methane can be lit with a match.
- H_2S is formed when spraying a soil sample with a 10% HCl solution and can be identified by the odour of rotten eggs.
- Fe^{2+} can be proven by oxidation with a 0.2% (mass by volume) solution of α,α-dipyridyl dissolved in 1 *N* ammonium acetate (NH_4OAc), pH 7. Take a soil sample and spray it with the solution. If Fe^{2+} is present, a strong red colour will develop. The test needs a freshly broken sample that has not yet been oxidized at the open profile wall. In neutral to alkaline soils, the colour is hardly visible. Caution: The solution is slightly toxic.

The following Table explains how to estimate the rH value using these field tests and the observed redoximorphic features (see Chapter 8.4.20). Report the rH range. Note that oximorphic features may be relic. Reductimorphic features may also be relic, if Fe and Mn have been removed in reduced form leaving behind a layer virtually free of Fe and Mn.

Table 8.59: Ranges of rH values and related soil processes as derived from redoximorphic features and from field tests of reducing conditions, Blume et al. (2011), page 24, FAO (2006), Table 36, modified

Criterion	Processes	rH value	Code
No redoximorphic features	Strongly aerated	> 33	R6
	Denitrification	29 - 33	
Oximorphic features of Mn; temporally no free oxygen present	Redox reactions of Mn	temporally 20 - 29	R5
Oximorphic features of Fe	Redox reactions of Fe	temporally < 20	R4
Blue-green to grey colour, Fe^{2+} ions always present (reduced areas show a positive α,α-dipyridyl test)	Formation of Fe^{II}/Fe^{III} oxides (green rust)	13 - 20	R3
Black colour due to metal sulfides (spraying with a 10% HCl solution causes the formation of H_2S)	Sulfide formation	10 - 13	R2
Flammable methane present	Methane formation	<10	R1

8.4.22 Initial weathering (m)

A major process of chemical weathering is the formation of Fe oxides (including hydroxides and oxide-hydroxides). If the weathering is initial, the Fe oxides may be concentrated in soil parts with easy access to oxygen, e.g. along pores. These parts have a distinctly redder hue or stronger chroma. Report the abundance as percentage of the exposed area.

8.4.23 Coatings and bridges (m)

Clay coatings and clay bridges

Illuviated clay consists of clay minerals, mostly together with oxides and in many cases together with organic matter. It covers surfaces of soil aggregates, coarse fragments and biopore walls as coatings (argillans), or it forms bridges between sand grains. The clay minerals give the coatings a shiny appearance. The oxides provide a colour that is more intensive (usually a higher Munsell chroma) than the colour of the matrix; organic matter provides a darker colour (usually a lower Munsell value) than the colour of the matrix (see Chapter 8.4.17). A hand lens (maximum 10x) may be helpful.

Report the abundance of

- clay coatings in % of the surfaces of soil aggregates, coarse fragments and/or biopore walls
- clay bridges between sand grains in % of involved sand grains.

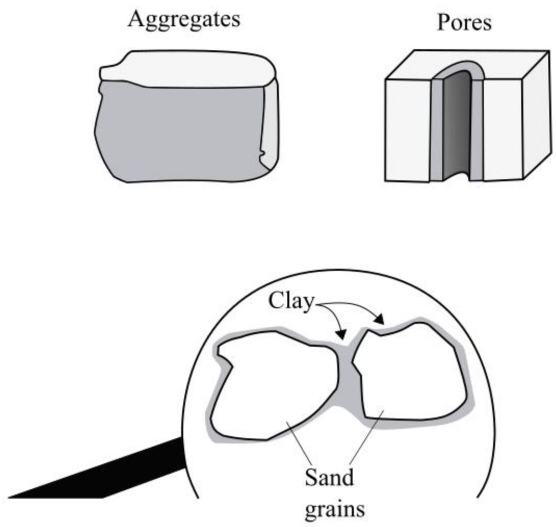


Figure 8.20: Clay coatings and clay bridges, Schoeneberger et al. (2012), 2-34

Organic matter coatings and oxide coatings on sand and coarse silt grains

Sand and coarse silt grains are mostly coated by organic matter and/or oxides. In certain layers, these coatings may be cracked. In other layers, these coatings may be missing.

Table 8.60: Organic matter coatings and oxide coatings on sand and/or coarse silt grains

Criterion	Code
Cracked coatings on sand grains	C
Uncoated sand and/or coarse silt grains	U
All sand and coarse silt grains coated without cracks	A

For C, report the percentage related to the estimated number of sand grains. For U, report the percentage related to the estimated number of sand and coarse silt grains.

8.4.24 Ribbon-like accumulations (m) (*)

Ribbon-like accumulations are thin, horizontally continuous accumulations within the matrix of another layer. Report the accumulated substance(s).

Table 8.61: Substances of ribbon-like accumulations

Substance	Code
Clay minerals	CC
Fe oxides and/or Mn oxides	OO
Organic matter	HH
Clay minerals and Fe oxides and/or Mn oxides	CO
Clay minerals and organic matter	CH
Fe oxides and/or Mn oxides and organic matter	OH
Clay minerals, Fe oxides and/or Mn oxides and organic matter	TO
No ribbon-like accumulations	NO

The term 'oxides', as used here, includes hydroxides and oxide-hydroxides. If clay minerals are accumulated, a ribbon-like accumulation is < 7.5 cm thick, in all other cases < 2.5 cm. If there are 2 or more ribbon-like accumulations in one layer, report the number of the accumulations and their combined thickness in cm. If clay minerals are accumulated (CC, CO, CH, TO), the ribbon-like accumulations are called **lamellae**.

8.4.25 Carbonates (o, m)

Take a soil sample, add drops of 1 M HCl and observe the reaction. This method detects primary and secondary calcium carbonates. Contrary to calcium carbonate, dolomite (calcium magnesium carbonate) shows little reaction with cold HCl. To identity dolomite, put some soil material in a spoon, add drops of 1 M HCl and heat it with a lighter underneath. If effervescence occurs only after heating, the presence of dolomite is indicated.

Content (*)

Report the carbonate content in the soil matrix and report, whether the reaction with HCl is immediate or only after heating.

Table 8.62: Carbonate contents, FAO (2006), Table 38

Criterion	Content	% (by mass)	Code
No visible or audible effervescence	Non-calcareous	0	NC
Audible effervescence but not visible	Slightly calcareous	> 0 - 2	SL
Visible effervescence	Moderately calcareous	> 2 - 10	MO
Strong visible effervescence, bubbles form a low foam	Strongly calcareous	> 10 - 25	ST
Extremely strong reaction, thick foam forms quickly	Extremely calcareous	> 25	EX

Table 8.63: Retarded reaction with HCl

Criterion	Code
Reaction with 1 M HCl immediate	I
Reaction with 1 M HCl only after heating	H

Secondary carbonates

Report the type of secondary carbonates. If more than one occurs, report up to four, the dominant one first. Report secondary carbonates only if **visible when moist**. Always check with HCl if it is really carbonate. Report the abundance as percentage for each form using Table 8.65 as a reference.

Table 8.64: Types of secondary carbonates

Type	Code
Masses (including spheroidal aggregations like white eyes (byeloglaska))	MA
Nodules and/or concretions	NC
Filaments (including continuous filaments like pseudomycelia)	FI
Coatings on soil aggregate surfaces or biopore walls	AS
Coatings on undersides of coarse fragments and of remnants of broken-up cemented layers	UR
No secondary carbonates	NO

Table 8.65: Reference for estimating the percentage of secondary carbonates

Code	Reference for estimating the percentage
MA, NC, FI	Exposed area (related to the fine earth plus accumulations of secondary carbonates of any size and any cementation class)
AS	Soil aggregate and biopore wall surfaces
UR	Underside surfaces

8.4.26 Gypsum (m)

Content

Report the gypsum content in the soil matrix. If readily soluble salts are absent or present in small amounts only, gypsum can be estimated by measuring the electrical conductivity in soil suspensions of different soil-water relations after 30 minutes (in the case of fine-grained gypsum). This method detects primary and secondary gypsum. Note: Higher gypsum contents may be differentiated by abundance of H_2O-soluble pseudomycelia/crystals and a soil colour with high value and low chroma.

Table 8.66: Gypsum contents in layers with little readily soluble salts, FAO (2006), Table 40

Electrical conductivity (EC)	Content	% (by mass)	Code
$\leq$ 1.8 dS m^{-1} in 10 g soil / 25 ml H_2O or $\leq$ 0.18 dS m^{-1} in 10 g soil / 250 ml H_2O	Non-gypsiferous	0	NG
> 0.18 - $\leq$ 1.8 dS m^{-1} in 10 g soil / 250 ml H_2O	Slightly gypsiferous	> 0 - 5	SL
> 1.8 dS m^{-1} in 10 g soil / 250 ml H_2O	Moderately gypsiferous	> 5 - 15	MO
	Strongly gypsiferous	> 15 - 60	ST
	Extremely gypsiferous	> 60	EX

Secondary gypsum

Secondary gypsum may be found as

- filaments (vermiform gypsum, pseudomycelia)
- gypsum crystal intergrowths or nodules (roses)
- pendants (normally fibrous) below coarse fragments and below remnants of broken-up cemented layers
- fibrous aggregates
- flour-like gypsum.

Gypsum is soft and can easily be ripped with a knife or broken between thumbnail and forefinger. Gypsum is very soluble, and when gypsum is found in soils that are not in extremely arid conditions, it can be assumed that it is secondary in almost all cases. Contrary to that, gypsiferous rocks and their fragments are primary. Fibrous gypsum, when occurring along veins within limestones or sandstones is also primary.

Report the total abundance (as percentage by exposed area, related to the fine earth plus accumulations of secondary gypsum of any size and any cementation class) of all types of secondary gypsum.

8.4.27 Secondary silica (m)

Form

Secondary silica (SiO_2) is off-white and predominantly consisting of opal and microcrystalline forms. It occurs as laminar caps, lenses, (partly) filled interstices, bridges between sand grains, and as coatings at surfaces of soil aggregates, biopore walls, coarse fragments, and remnants of broken-up cemented layers. Report the type of secondary silica. If more than one type occurs, report up to two, the dominant one first. Note: Durinodes are often coated with secondary carbonates.

Table 8.67: Types of secondary silica

Type	Code
Nodules (durinodes)	DN
Accumulations within a layer, cemented by secondary silica	CH
Remnants of a layer that has been cemented by secondary silica	FC
Other accumulations	OT
No secondary silica	NO

Size

If a layer shows durinodes and/or remnants of a layer that has been cemented by secondary silica, report their size class. The Table indicates the average length of the greatest dimension.

Table 8.68: Size of durinodes and remnants of a layer that has been cemented by secondary silica

Size (cm)	Size class	Code
≤ 0.5	Very fine	VF
> 0.5 - 1	Fine	FI
> 1 - 2	Medium	ME
> 2 - 6	Coarse	CO
> 6	Very coarse	VC

Abundance

Report the total percentage (by exposed area) of secondary silica. For a cemented layer, this percentage refers to the fine earth plus accumulations of secondary silica of any size and any cementation class. For durinodes and remnants of a cemented layer, this percentage comprises the secondary silica visible at their surfaces. If a layer shows durinodes and/or remnants of a cemented layer, report in addition the percentage (by volume) of those durinodes and remnants that have a diameter ≥ 1 cm.

8.4.28 Readily soluble salts (o, m)

Readily soluble salts are precipitated in dry soil and dissolved in moist soil. They are more soluble than gypsum. The presence of readily soluble salts is checked by measuring the electrical conductivity in the saturation extract (EC_{SE}). In the saturation extract, the soil is completely moist, but has no visible water surplus. This is not easy to achieve.

Alternatively, one can measure the electrical conductivity in an extract of 10 g soil with 25 ml aqua dest. ($EC_{2.5}$). Mix soil and water carefully, let it rest for at least 30 minutes and measure the electrical conductivity in the clear solution in dS m^{-1}. It must then be transformed into the EC_{SE} according to the following equation: $EC_{SE} = 250 \times EC_{2.5} \times (WC_{SE})^{-1}$.

WC_{SE} is the water content in the saturation extract. It can be estimated in mineral soils from texture (see

Chapter 8.4.9) and C_{org} content (see Chapter 8.4.36) and in peat soils from the degree of decomposition (see Chapter 8.4.41) with the help of the following Tables. High amounts of coarse fragments reduce the water content.

Report the electrical conductivity of the saturation extract in dS m^{-1}.

Table 8.69: Estimation of the water content of the saturation extract of mineral layers, DVWK (1995), FAO (2006), Table 43

	Water content of the saturation extract (WC_{SE}) (g water / 100 g soil)					
Texture class	**C_{org} content (%)**					
	< 0.25	**0.25 - < 0.5**	**0.5 - < 1**	**1 - < 2**	**2 - < 4**	**4 - < 20**
CS	5	6	8	13	21	35
MS	8	9	11	16	24	38
FS, VFS	10	11	13	18	26	40
LS, SL(< 10% clay)	14	15	17	22	30	45
SiL(< 10% clay)	17	18	20	25	34	49
Si	19	20	22	27	36	51
SL(≥ 10 % clay)	22	23	26	31	39	55
L	25	26	29	34	42	58
SiL(≥ 10% clay)	28	29	32	37	46	62
SCL	32	33	36	41	50	67
CL, SiCL	44	46	48	53	63	80
SC	51	53	55	60	70	88
SiC, C(< 60% clay)	63	65	68	73	83	102
C(≥ 60% clay)	105	107	110	116	126	147

Table 8.70: Estimation of the water content of the saturation extract of organic layers, DVWK (1995), FAO (2006), Table 43

Degree of decomposition (by volume, related to the fine earth plus all dead plant residues)	**Water content of the saturation extract (WC_{SE}) (g water / 100 g soil)**
The organic material consists only of recognizable dead plant tissues	80
After rubbing, > three fourths, but not all, of the organic material consist of recognizable dead plant tissues	120
After rubbing, ≤ three fourths and > two thirds of the organic material consist of recognizable dead plant tissues	170
After rubbing, ≤ two thirds and > one sixth of the organic material consist of recognizable dead plant tissues	240
After rubbing, ≤ one sixth of the organic material consists of recognizable dead plant tissues	300

8.4.29 Field pH (o, m)

Report the field pH. For its determination, two different methods are recommended: the colorimetric and the potentiometric method. The colorimetric method only allows the pH measurement in distilled water, while the potentiometric method allows the measurement in different solutions.

Colorimetric method

Mix soil and distilled water in a 1:1 ratio (volume:volume) and stir the mixture thoroughly. Allow the mixture to settle until a supernatant forms. Submerge an indicator paper in the supernatant and report the result.

Potentiometric method

Table 8.71 shows common solutions and mixing ratios. Mix air-dry soil with the solution thoroughly. Allow the mixture to settle until a supernatant forms. Measure the pH value with a pH electrode, ideally with the help of a tripod. Wait until the measured value is steady. Report the measured value together with the code indicating solution and mixing ratio.

Table 8.71: Potentiometric pH measurement

Solution	**Mixing ratio (volume:volume)**	**Code**
Distilled water (H_2O)	1:1	W11
Distilled water (H_2O)	1:5	W15
$CaCl_2$, 0.01 M	1:5	C15
KCl, 1 M	1:5	K15

8.4.30 Consistence (m)

Consistence is the degree and kind of cohesion and adhesion that soil exhibits. This Chapter refers to the consistence of the matrix and of non-redoximorphic features. For the consistence of redoximorphic features, see Chapter 8.4.20. Consistence is reported separately for cemented and non-cemented (parts of) layers. If a specimen of soil does not fall into pieces by applying low forces, one has to check, whether it is cemented.

Presence and volume of cementation

For checking cementation, different specimens have to be taken, depending on soil characteristics. For checking surface crusts and platy aggregates, take a specimen that is approximately 1 to 1.5 cm long by 0.5 cm thick (or the thickness of occurrence, if < 0.5 cm thick). In all other cases, take a specimen, around 2.6 to 3 cm long at all dimensions. Take the specimen air-dried and submerge it in water for at least 1 hour. If it slakes like forming a soup, it is not cemented. Otherwise, it is cemented. Report the percentage (by volume, related to the whole soil) of the layer that is cemented.

Cementing agents (cemented soil)

Report the cementing agents. If more than one is present, report up to three, the dominant one first. The term ‘oxides’, as used here, includes hydroxides and oxide-hydroxides.

Table 8.72: Cementing agents, Schoeneberger et al. (2012), 2-64

Cementing agent	**Code**
Carbonates	CA
Gypsum	GY
Readily soluble salts	RS
Silica	SI
Organic matter	OM
Fe oxides	FE
Mn oxides	MN
Al	AL
Ice, < 75% (by volume)	IA
Ice, ≥ 75% (by volume)	IM

Cementation (cemented soil) and rupture resistance (non-cemented soil)

For checking this feature, different specimens have to be taken, depending on soil characteristics. For checking surface crusts and platy aggregates, take a specimen that is approximately 1 to 1.5 cm long by 0.5 cm thick (or the thickness of occurrence, if < 0.5 cm thick) and apply force perpendicular to its greatest dimension. In all other cases, take a specimen, around 2.6 to 3 cm long at all dimensions, and apply force. Observe the force needed for failure and report the cementation class (cemented soil) or the rupture resistance class (non-cemented soil). The rupture resistance has to be detected in moist soil and, if possible, also in dry soil. If specimens of the required size are not obtainable, use the following equation to calculate the stress at failure (Table 8.73 and Table 8.74) (Schoeneberger et al., 2012):

$(2.8\text{ cm/cube length cm})^2 \times (\text{estimated stress (N) at failure})$

e.g. for a 5.6-cm cube $[(2.8/5.6)^2 \times 20\text{ N}] = 5\text{ N} \rightarrow$ Very friable (moist).

Table 8.73: Cementation, Schoeneberger et al. (2012), 2-63

Criterion	Class	Code
Intact specimen not obtainable or very slight force between fingers, < 8 N	Not cemented	NOC
Slight force between fingers, 8 - < 20 N	Extremely weakly cemented	EWC
Moderate force between fingers, 20 - < 40 N	Very weakly cemented	VWC
Strong force between fingers, 40 - < 80 N	Weakly cemented	WEC
Moderate force between hands, 80 - < 160 N	Moderately cemented	MOC
Foot pressure by full body weight, 160 - < 800 N	Strongly cemented	STC
Blow of < 3 J (3 J = 2 kg dropped 15 cm) and does not fail under foot pressure by full body weight (800 N)	Very strongly cemented	VSC
Blow of ≥ 3 J (3 J = 2 kg dropped 15 cm)	Extremely strongly cemented	EXC

Table 8.74: Rupture resistance, non-cemented soil, Schoeneberger et al. (2012), 2-63

Criterion	Moist rupture resistance		Dry rupture resistance	
	Class	Code	Class	Code
Intact specimen not obtainable	Loose	LO	Loose	LO
Very slight force between fingers, < 8 N	Very friable	VF	Soft	SO
Slight force between fingers, 8 - < 20 N	Friable	FR	Slightly hard	SH
Moderate force between fingers, 20 - < 40 N	Firm	FI	Moderately hard	MH
Strong force between fingers, 40 - < 80 N	Very firm	VI	Hard	HA
Moderate force between hands, 80 - < 160 N	Extremely firm	EI	Very hard	VH
Foot pressure by full body weight, 160 - < 800 N	Slightly rigid	SR	Extremely hard	EH
Blow of < 3 J (3 J = 2 kg dropped 15 cm) and does not fail under foot pressure by full body weight (800 N)	Rigid	RI	Rigid	RI
Blow of ≥ 3 J (3 J = 2 kg dropped 15 cm)	Very rigid	VR	Very rigid	VR

Susceptibility for cementation (non-cemented soil)

Some layers are prone to cementation after repeated drying and wetting. Report the susceptibility.

Table 8.75: Susceptibility for cementation

Criterion	Code
Cementation after repeated drying and wetting	CW
No cementation after repeated drying and wetting	NO

Manner of failure (non-cemented to weakly cemented soil)

Report the manner of failure (brittleness). Take a moist specimen, around 3 cm long at all dimensions, press it between thumb and forefinger and observe it when it ruptures.

Table 8.76: Types of manner of failure (brittleness), Schoeneberger et al. (2012), 2-65

Criterion	Type	Code
Abruptly (pops or shatters)	Brittle	BR
Before compression to one half the original thickness	Semi-deformable	SD
After compression to one half the original thickness	Deformable	DF

Plasticity (non-cemented soil)

Plasticity is the degree to which reworked soil can be permanently deformed without rupturing. It is estimated at a water content where the maximum plasticity is expressed (usually moist). Make a roll (wire, sausage) of soil, 4 cm long, roll it to smaller diameters and report the plasticity.

Table 8.77: Types of plasticity, Schoeneberger et al. (2012), 2-66

Criterion	Type	Code
Does not form a roll 6 mm in diameter, or if a roll is formed, it cannot support itself if held on end.	Non-plastic	NP
6 mm diameter roll supports itself; 4 mm diameter roll does not.	Slightly plastic	SP
4 mm diameter roll supports itself; 2 mm diameter roll does not.	Moderately plastic	MP
2 mm diameter roll supports itself.	Very plastic	VP

Penetration resistance

Measuring the penetration resistance is recommended for layers that are cemented or have a rupture-resistance class of firm or more (moist). Non-cemented soil should be at field capacity for measurement. Use a penetrometer and report the penetration resistance in MPa. The measurement should be repeated at least five times to calculate a reliable average value.

8.4.31 Surface crusts (m)

A crust is a thin layer of soil constituents bound together into a horizontal mat or into small polygonal plates (see Schoeneberger et al., 2012). Soil crusts develop in the first mineral layer(s) and are formed by a sealing agent of physical, chemical and/or biological origin. The characteristics of the crust are different from the underlying layers. Typically, soil crusts change the infiltration rate and stabilize loose soil aggregates. They may be present permanently or only when the soil is dry. The area covered is reported in Chapter 8.3.7. They may be cemented or not, which is reported in Chapter 8.4.30.

Report the sealing agent. If more than one is present, report up to three, the dominant one first.

Table 8.78: Sealing agent of surface crusts

Type	Code
Physical, permanent	PP
Physical, only when dry	PD
Chemical, by carbonates	CC
Chemical, by gypsum	CG
Chemical, by readily soluble salts	CR
Chemical, by silica	CS
Biological, by cyanobacteria	BC
Biological, by algae	BA
Biological, by fungi	BF

Biological, by lichens	BL
Biological, by mosses	BM
No crust present	NO

8.4.32 Continuity of hard materials and cemented layers (m)

Continuous rock, technic hard material and cemented layers may have fractures, which are filled by non-cemented soil material. Report the total percentage (by volume, related to the whole soil) that is occupied by the fractures and the average distance between the fractures in cm. This has also to be reported, if the hard or cemented material starts at the soil surface. If a cemented layer is not only fractured but broken up, the remnants are reported with the coarse fragments (see Chapter 8.4.7).

8.4.33 Volcanic glasses and andic characteristics (o, m)

Volcanic glasses in the sand and coarse silt fraction

Report the percentage of the particles in the sand and coarse silt fraction (> 20 µm - ≤ 2 mm) that consist of volcanic glasses. Use a hand lens or microscope.

Table 8.79: Abundance of particles in the sand and coarse silt fraction that consist of volcanic glasses

% of particles	Abundance class	Code
0	None	N
> 0 - 5	Few	F
> 5 - 30	Common	C
> 30	Many	M

If the percentage is around a limit value, take a soil sample, gain the sand and coarse silt fraction by sieving, lay the particles on a sheet, and count the glass particles and the non-glass particles.

Andic characteristics

Andic properties are defined by laboratory data. In the field, one can recognize a low bulk density, a dark colour and a high organic matter content. In addition, there are two specific field tests indicative of *andic properties*.

Thixotropy: Layers with *andic properties* show a high variable charge allowing the absorption of much water that can easily be driven out by shaking but will be absorbed again, after a while. Procedure: Take a soil sample and make a sphere of about 2.5 cm in diameter. Wait until any moisture films have disappeared. Place the sphere in cupped hands and shake it. If moisture films appear at the surface of the sphere, the soil shows thixotropy. After a while, the moisture films will disappear again.

NaF test according to Fieldes and Perrott (1966), after FAO (2006): A pH_{NaF} of > 9.5 indicates the presence of abundant allophanes and imogolites and/or organo-aluminium complexes. Aluminium sorbs F^- ions while releasing OH^- ions. The test is indicative for most layers with *andic properties*, except for those very rich in organic matter. However, the same reaction occurs in *spodic horizons* and in acidic clayey soils that are rich in aluminium-interlayered clay minerals; soils with free carbonates also react. Before applying the NaF test, check the soil pH in water or KCl (the NaF test is not suitable for alkaline soils) and the presence of free carbonates (using the HCl test). Procedure: Place a small amount of soil on a filter paper previously soaked in phenolphthalein and add some drops of 1 M NaF (adjusted to pH 7.5). A positive reaction is indicated by a fast change to an intense red colour. Alternatively, measure the pH of a suspension of 1 g soil in 50 ml 1 M NaF (adjusted to pH 7.5) after waiting 2 minutes. A pH of > 9.5 is an indication of *andic properties*.

Report the results.

Table 8.80: Thixotropy and NaF field test

Criterion	Code
Positive NaF test	NF
Thixotropy	TH
Positive NaF test and thixotropy	NT
None of the above	NO

8.4.34 Permafrost features (o, m)

Cryogenic alteration

Estimate the total percentage (by exposed area, related to the whole soil) affected by cryogenic alteration. Report up to three features, the dominant one first, and report the percentage for each feature separately.

Table 8.81: Cryogenic alteration

Feature	Code
Ice wedge	IW
Ice lens	IL
Disrupted lower layer boundary	DB
Organic involutions in a mineral layer	OI
Mineral involutions in an organic layer	MI
Separation of coarse material and fine material	CF
Other	OT
None	NO

Layers with permafrost

A layer with permafrost has continuously for ≥ 2 consecutive years one of the following:

- massive ice, cementation by ice or readily visible ice crystals, or
- a soil temperature of < 0 °C and insufficient water to form readily visible ice crystals.

Report whether a layer has permafrost.

Table 8.82: Layers with permafrost

Criterion	Code
Massive ice, cementation by ice or readily visible ice crystals	I
Soil temperature of < 0 °C and insufficient water to form readily visible ice crystals	T
No permafrost	N

8.4.35 Bulk density (m) (*)

Estimate the packing density using a knife with a blade approx. 10 cm long.

Table 8.83: Packing density

Criterion	Class	Code
Knife penetrates completely even when applying low forces	Very loose	VL
Knife penetrates completely when forces are applied	Loose	LO
Knife penetrates half when forces are applied	Intermediate	IN
Only the knifepoint penetrates when forces are applied	Firm	FR
Knife does not (or only a little bit) penetrate when forces are applied	Very firm	VR

With the following Figure, the bulk density is determined from packing density and soil texture (see Chapter 8.4.9). If C_{org} content is > 1%, bulk density must be reduced by 0.03 kg dm^{-3} for each 0.5% increment in C_{org} content. Report the bulk density with an accuracy of one decimal.

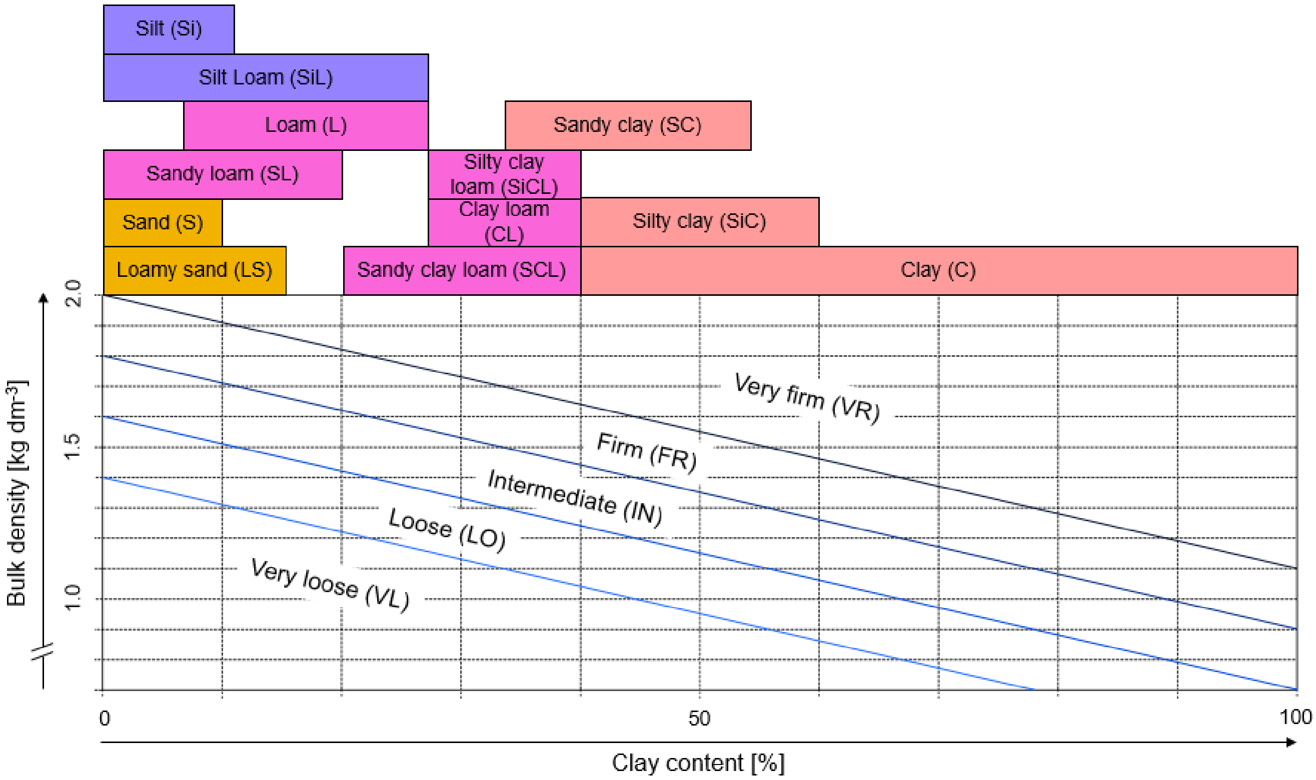


Figure 8.21: Estimation of bulk density from packing density and texture, FAO (2006), Figure 7, modified

8.4.36 Soil organic carbon (C_{org}) (m)

Estimation of the content (*)

Report the estimated organic carbon content. It is based on the Munsell value, moist, and the texture. If chroma is 3.5 - 6, use value 0.5 higher (e.g. if you reported a Munsell colour of 10YR 3/4, use a value of 3.5 for estimating soil organic carbon). If chroma is > 6, use value 1 higher.
Caution: The Munsell value is also influenced by parent material, carbonates and redox conditions.

Table 8.84: Estimation of organic carbon contents in a moist sample, Blume et al. (2011), modified

Munsell value	**Organic carbon content (%), depending on soil texture class**		
	S	**LS, SL, L**	**SiL, Si, SiCL, CL, SCL, SC, SiC, C**
≥ 6	< 0.2	< 0.2	< 0.2
5.5	< 0.2	< 0.2	0.2 - < 0.5
5	0.2 - < 0.5	0.2 - < 0.5	0.2 - < 0.5
4.5	0.2 - < 0.5	0.2 - < 0.5	0.2 - < 0.5
4	0.2 - < 0.5	0.2 - < 0.5	0.2 - < 1.0
3.5	0.2 - < 1.0	0.5 - < 1.0	0.5 - < 2.5
3	0.5 - < 2.5	1.0 - < 2.5	1.0 - < 5.0
2.5	1.0 - < 5.0	≥ 2.5	≥ 2.5
≤ 2	≥ 2.5		

Natural accumulations of organic matter

This Chapter refers to accumulations of organic matter in form of discrete bodies. They have usually a lower value than the surrounding material. Report here all accumulations that are natural or that are a side effect of human activities. Additions of *artefacts* see Chapter 8.4.8 and of human-transported material see Chapter 8.4.39. If black carbon is purposefully made by humans, it is considered to be an artefact. Organic matter accumulations due to animal activity are reported twice, once here and once in Chapter 8.4.38.

Table 8.85: Types of accumulation of organic matter

Type	Code
Filled earthworm burrows	BU
Filled krotowinas	KR
Organic matter coatings at surfaces of soil aggregates and biopore walls (no visible other material in the coatings)	CO
Black carbon (e.g. charcoal, partly charred particles, soot))	BC
No visible accumulation of organic matter	NO

Report up to three types, the dominant one first, and report the percentage (by exposed area) for each type separately. Black carbon has to be additionally reported as percentage of the exposed area (related to the fine earth plus black carbon of any size).

8.4.37 Roots (o, m)

Count the number of roots per dm^2, separately for the two diameter classes, and report the abundance classes.

Table 8.86: Abundance of roots, FAO (2006), Table 80

Number ≤ 2 mm	Number > 2 mm	Abundance class	Code
0	0	None	N
1 - 5	1 - 2	Very few	V
6 - 10	3 - 5	Few	F
11 - 20	6 - 10	Common	C
21 - 50	11 - 20	Many	M
> 50	> 20	Abundant	A

8.4.38 Results of animal activity (o, m)

Report the animal activity that has visibly changed the features of the layer. If applicable, report up to 5 types, the dominant one first. Report the percentage (by exposed area), separately for mammal activity, bird activity, worm activity, insect activity and unspecified activity.

Table 8.87: Types of animal activity, FAO (2006), Table 82, modified

Type	Code
Mammal activity	
Open large burrows	MO
Infilled large burrows (krotovinas)	MI
Bird activity	
Bones, feathers, sorted gravel of similar size	BA
Worm activity	
Earthworm channels	WE
Worm casts	WC
Insect activity	

Termite channels and nests	IT
Ant channels and nests	IA
Other insect activity	IO
Burrows (unspecified)	BU
No visible results of animal activity	NO

8.4.39 Human alterations (o, m)

Additions of human-transported natural material

Natural material is any material not meeting the criteria of *artefacts* (see Chapter 8.4.8). Report the percentage (by volume, related to the whole soil), which may range from very little up to 100%, for each addition separately. If more than one occurs, report up to three, the dominant one first. For mineral additions ≤ 2 mm, report additionally, if possible, the texture class (see Chapter 8.4.9), the carbonate content (see Chapter 8.4.25) and the C_{org} content (see Chapter 8.4.36).

Table 8.88: Artificial additions of natural material

Material	Code
Organic	OR
Mineral, > 2 mm	ML
Mineral, ≤ 2 mm	MS
No additions	NO

In-situ alterations

Report in-situ alterations. If more than one applies, report up to two, the dominant one first.

Table 8.89: In-situ alterations

Type	Code
Ploughing, annually	PA
Ploughing, at least once every 5 years	PO
Ploughing in the past, not ploughed since > 5 years	PP
Ploughing, unspecified	PU
Remodelled (e.g. single ploughing)	RM
Loosening	LO
Compaction, other than a plough pan	CP
Structure deterioration, other than by ploughing or remodelling	SD
Other	OT
No in-situ alteration	NO

Soil aggregate formation after additions or after in-situ alterations

Adding or mixing may combine materials richer and poorer in C_{org}. A new granular structure may form combining the two. Report, to which extent this process has happened. Use a hand lens.

Table 8.90: Aggregate formation after adddditions or after in-situ alterations

Criterion	Code
New granular structure present throughout the layer	T
New granular structure present in places, but in other places the added or mixed materials and the previously present materials lie isolated from each other	P
No new granular structure present	N

8.4.40 Parent material (m)

Report the parent material. Use the help of a geological map.

Table 8.91: Types of parent material, FAO (2006), Table 12, modified

Major class	Group	Code	Type	Code
Igneous Rock	Felsic igneous	IF	Granite	IF1
			Quartz-diorite	IF2
			Grano-diorite	IF3
			Diorite	IF4
			Rhyolite	IF5
	Intermediate igneous	II	Andesite, trachyte, phonolite	II1
			Diorite-syenite	II2
	Mafic igneous	IM	Gabbro	IM1
			Basalt	IM2
			Dolerite	IM3
	Ultramafic igneous	IU	Peridotite	IU1
			Pyroxenite	IU2
			Serpentinite	IU3
	Pyroclastic	IP	Tuff, tuffite	IP1
			Volcanic scoria/breccia	IP2
			Volcanic ash	IP3
			Ignimbrite	IP4
Metamorphic rock	Felsic metamorphic	MF	Quartzite	MF1
			Gneiss, migmatite	MF2
			Slate, phyllite (pelitic rocks)	MF3
			Schist	MF4
	Mafic metamorphic	MM	Slate, phyllite (pelitic rocks)	MM1
			(Green)schist	MM2
			Gneiss rich in Fe-Mg minerals	MM3
			Metamorphic limestone (marble)	MM4
			Amphibolite	MM5
			Eclogite	MM6
	Ultramafic metamorphic	MU	Serpentinite, greenstone	MU1
Sedimentary rock (consolidated)	Clastic sediments	SC	Conglomerate, breccia	SC1
			Sandstone, greywacke, arkose	SC2
			Silt-, mud-, claystone	SC3
			Shale	SC4
			Ironstone	SC5
	Carbonatic, organic	SO	Limestone, other carbonate rock	SO1
			Marl and other mixtures	SO2
			Coals, bitumen and related rocks	SO3
	Evaporites	SE	Anhydrite, gypsum	SE1
			Halite	SE2

Sedimentary rock (unconsolidated)	Weathered residuum	UR	Bauxite, laterite	UR1
	Fluvial	UF	Sand and gravel	UF1
			Clay, silt and loam	UF2
	Lacustrine	UL	Sand	UL1
			Silt and clay, < 20% $CaCO_3$ equivalent, little or no diatoms	UL2
			Silt and clay, < 20% $CaCO_3$ equivalent, many diatoms	UL3
			Silt and clay, ≥ 20% $CaCO_3$ equivalent (marl)	UL4
	Marine, estuarine	UM	Sand	UM1
			Clay and silt	UM2
	Colluvial	UC	Slope deposits	UC1
			Lahar	UC2
			Deposit of soil material	UC3
	Aeolian	UE	Loess	UE1
			Sand	UE2
	Glacial	UG	Moraine	UG1
			Glacio-fluvial sand	UG2
			Glacio-fluvial gravel	UG3
	Cryogenic	UK	Periglacial rock debris	UK1
			Periglacial solifluction layer	UK2
	Organic	UO	Rainwater-fed peat (bog)	UO1
			Groundwater-fed peat (fen)	UO2
			Lacustrine (organic limnic sediments)	UO3
	Anthropogenic/ technogenic	UA	Redeposited natural material	UA1
			Industrial/artisanal deposits	UA2
	Unspecified deposits	UU	Clay	UU1
			Loam and silt	UU2
			Sand	UU3
			Gravelly sand	UU4
			Gravel, broken rock	UU5

If the type is unknown, just report the group. Note: the old terms ‘acid’ and ‘basic’ rocks were replaced by ‘felsic’ and ‘mafic’.

8.4.41 Degree of decomposition in organic layers and presence of dead plant residues (o) (*)

Degree of decomposition

This Chapter refers to the transformation of visible plant tissues into visibly homogeneous organic matter. Rub the soil material and report the percentage of visible plant tissues (by volume, related to the fine earth plus all dead plant residues).

Subdivisions of the Oa horizon

If an Oa horizon (see Annex 3, Chapter 10.2) is present, report its subdivisions.

Table 8.92: Subdivisions of the Oa horizon

Criterion	Type	Code
Breaks into longitudinal pieces with sharp edges	Sharp-edged	SE
Breaks into longitudinal pieces with unsharp edges	Compact	CO
Breaks into crumbly pieces or breaks powdery	Crumbly	CR

Dead natural plant residues

This Chapter refers to dead natural plant residues. For treated plant residues, see *artefacts* (see Chapter 8.4.8). Report up to two types of plant residues, the dominant one first, and give the percentage (by volume, related to the fine earth plus all dead plant residues) for each type separately.

Table 8.93: Dead residues of specific plants

Type of plant residues	Code
Wood	W
Moss fibres	S
Other plants	O
No dead plant residues	N

8.5 Sampling

We describe here the sampling of the terrestrial organic surface layers and the conventional and volumetric sampling of mineral layers, all for the standard analyses described in Annex 2 (Chapter 9). Sampling of other layers requires special techniques that are not described here.

8.5.1 Preparation of sampling bags

Use strong, moisture-resistant bags (transparent, if possible) for sampling. Write the sampling details twice: once on the bag and once on a piece of paper to be put into the bag. If you want to transfer sampling rings to the laboratory, write the sampling details on the ring. Always use a permanent marker.
Write down the following details:

- Profile name
- Conventional (C) / Volumetric (V)
- Layer upper and lower depth
- Layer designation (see Annex 3, Chapter 10).

Example: *Gombori Pass 1 - V - 0-10 cm - Ah*.
Make sure to seal the bags after filling in the sample.

8.5.2 Sampling of organic layers

Generally, the fine earth plus all dead plant residues are sampled. For the decision if a layer consists of organic material, the organic carbon is measured in a sample containing the fine earth plus the dead plant residues of any length and a diameter ≤ 5 mm (excluding *artefacts*).

For sampling the terrestrial organic surface layers, use a quadratic steel frame, for instance with 30 cm side length. Use a rubber hammer to drive the frame through the organic surface layers and a few centimetres into the mineral soil. The frame must enter the soil evenly, do not drive in one side first and then the other. Collect the organic surface material manually, sample the litter layer and every O horizon separately. Be very careful to sample all organic surface layers but no mineral layers.

8.5.3 Conventional sampling of mineral layers

Use a scraper to sample every layer separately and along its entire height and width. Start with the lowest layer. Make sure that you only sample one layer at a time, avoid that material from one layer falls into the other.

8.5.4 Volumetric sampling of mineral layers

At the soil surface, determine an area large enough for the appropriate number of sampling rings (e.g. 3 rings). The area must be adjacent to the profile wall and close to the measuring tape. In this area, remove the organic surface layers and start sampling layer by layer from top to down. The thickness of a mineral layer may be larger or smaller than the height of a sampling ring or it may be equal (Figure 8.22).

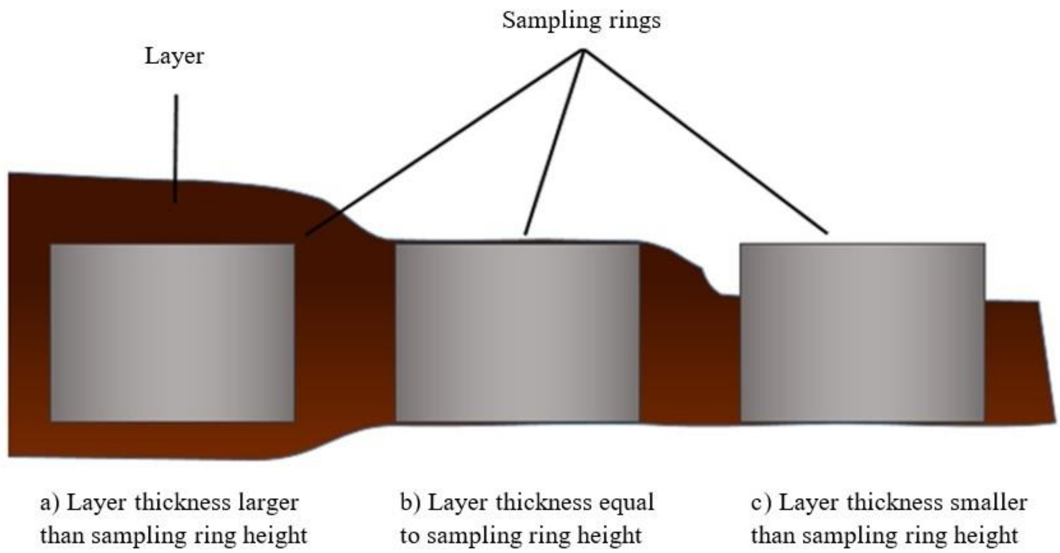


Figure 8.22: Volumetric sampling

a) If the thickness of the layer is larger, subtract the height of the sampling ring from the layer thickness and divide the difference by 2. This result equals the thickness of soil material that has to be removed starting from the upper layer boundary.
b) If the thickness of the layer is equal, it is very important that the surface is plane.
c) If the thickness of the layer is smaller, you will need the thickness of the layer in relation to the height of the sampling ring for calculating the sampled volume.

For each layer, form a plane surface. If the soil is dryer than field capacity, moisten the surface slowly with water from a spray bottle. Wait until the soil is moist, avoid a water surplus. Then drive in the sampling rings slowly and completely but avoid compacting soil material. For driving in the sampling rings, use a hammer and a piece of wood. The piece should be made of durable wood and have plane surfaces at the top and the bottom. It should be just large enough to cover one sampling ring. If the ring does not move in without deforming, stop driving it in. Try to find a better position.

To take out the rings, penetrate the soil with a spatula just beneath the ring and take it out. If the soil is hard to penetrate, you may use a knife with a serrated blade (bread knife). When necessary, cut roots off. When taking the rings out, make sure that no soil material is lost from inside the rings. Place a cap on the top side and turn the ring upside down. Now make the bottom surface plane and place another cap.

If you want to do further physical analyses, transfer the ring to the laboratory. If the layer thickness is smaller than the height of the ring (case c), fill up the volume with a resin. If you just want to determine the soil mass, you may empty the soil material from the ring into the designated bag and reuse the ring.

To determine the soil mass of a sample of a certain volume, you may also use coated clods (see Annex 2, Chpater 9.5).

8.6 References

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9 Annex 2: Summary of analytical procedures for soil characterization

This annex provides summaries of recommended analytical procedures to be used for soil characterization for the World Reference Base for Soil Resources. Full descriptions can be found in *Procedures for soil analysis* (Van Reeuwijk, 2002) and the USDA *Kellogg Soil Survey Laboratory Methods Manual* (Soil Survey Staff, 2014).

9.1 Sample preparation

Samples are air-dried or alternatively oven-dried at a maximum of 40 °C. The fine earth is obtained by sieving the dry sample with a 2-mm sieve. Clods not passing through the sieve are crushed (not ground) and sieved again. Coarse fragments and roots not passing through the sieve are treated separately.

In special cases where air-drying causes unacceptable irreversible changes in certain soil properties (e.g. in peat and in soils with *andic properties*), samples are kept and treated in the field-moist state. These samples should be kept under cool conditions and analyzed within a few weeks after sampling.

9.2 Moisture content

Calculation of contents is done on the basis of dry (105 °C) soil mass.

9.3 Particle-size analysis

The mineral part of the soil is separated into various size fractions and the proportion of these fractions is determined. The determination comprises all material, i.e. including coarse fragments, but the procedure itself is applied to the fine earth (≤ 2 mm) only. The particle-size classes according to ISO 11277:2009 are given in the Table:

Table 9.1: Particle-size classes

Particle-size class	**Diameter of particles**
Fine earth	all particles ≤ 2 mm
Sand	> 63 µm - ≤ 2 mm
Very coarse sand	> 1250 µm - ≤ 2 mm
Coarse sand	> 630 µm - ≤ 1250 µm
Medium sand	> 200 µm - ≤ 630 µm
Fine sand	> 125 µm - ≤ 200 µm
Very fine sand	> 63 µm - ≤ 125 µm
Silt	> 2 µm - ≤ 63 µm
Coarse silt	> 20 µm - ≤ 63 µm
Fine silt	> 2 µm - ≤ 20 µm
Clay	≤ 2 µm
Coarse clay	> 0.2 µm - ≤ 2 µm
Fine clay	≤ 0.2 µm

The pre-treatment of the sample is aimed at complete dispersion of the primary particles. Therefore, cementing materials (usually of secondary origin) such as organic matter and calcium carbonate may have to be removed. In some cases, de-ferration also needs to be applied. The amount of cementing material has to be documented. However, depending on the aim of study, it may be fundamentally wrong to remove cementing materials. Thus, all pre-treatments are considered optional. However, for soil characterization purposes, removal of organic matter by H_2O_2 and of carbonates by HCl is routinely carried out. After this pre-treatment, the sample is shaken with a dispersing agent and sand is separated from clay and silt with a 63-µm sieve. The sand is fractionated by dry sieving; the clay and silt fractions are determined by the pipette method or, alternatively, by the hydrometer method.

9.4 Water-dispersible clay

This is the clay content found when the sample is dispersed with water without any pre-treatment to remove cementing compounds and without use of a dispersing agent. The proportion of water-dispersible clay to total clay can be used as a structure stability indicator.

9.5 Bulk density

Density is defined as mass per unit volume. Soil bulk density is the ratio of the mass of solids to the total or bulk volume and is given at dry state. This total volume includes the volume of both solids and pore space. The volume and therefore the bulk density changes with swelling and shrinking, which is related to the water content. For that reason, the water status of the sample prior to drying must be specified.

Two different procedures can be used:

- *Undisturbed core samples*. A metal cylinder of known volume is pressed into the soil. The moist sample mass is recorded. This may be the field-moist state or the state after equilibrating the sample at a specified water tension. The sample is then dried at 105 °C and weighed again. The bulk density is the ratio of dry mass to volume (related to the determined water content and/or the specified water tension).
- *Coated clods.* Field-occurring clods are coated with plastic lacquer (e.g. Saran dissolved in methyl ethyl ketone) to allow underwater determination. This gives the volume of the clod. The moist sample mass is recorded. This may be the field-moist state or the state after equilibrating the clod at a specified water tension. The sample is then dried at 105 °C and weighed again. The bulk density is the ratio of dry mass to volume (related to the determined water content and/or the specified water tension).

If the sample contains many coarse fragments, the coarse fragments are sieved out after drying and then their mass and volume are determined separately. With that, the bulk density of the fine earth is calculated. The determination of bulk density is very sensitive to natural variability, particularly caused by non-representativeness of the samples (coarse fragments, cementations, cracks, roots, etc.). Therefore, determinations should always be made at least in triplicate.

9.6 Coefficient of linear extensibility (COLE)

The COLE gives an indication of the reversible shrink–swell capacity of a soil. It is calculated as the ratio of the difference between the moist length and the dry length of a clod to its dry length: $(L_m - L_d)/L_d$, in which L_m is the length at 33 kPa tension and L_d the length when dry (105 °C).

9.7 pH

The pH of the soil is measured potentiometrically in the supernatant suspension of a soil:liquid mixture. If not stated otherwise, soil:liquid are in a ratio of 1:5 (volume:volume) (according to ISO standards). The liquid is either distilled water (pH_{water}) or a 1 *M* KCl solution (pH_{KCl}). However, in some definitions, a 1:1 soil:water ratio is used.

9.8 Organic carbon

Many laboratories use auto-analysers (e.g. dry combustion). In these cases, a qualitative test for carbonates on effervescence with HCl is recommended, and if applicable, a correction for inorganic C (see Chapter 9.9) is required.

Otherwise, the *Walkley–Black method* is followed. This involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulfuric acid at about 125 °C. The residual dichromate is titrated against ferrous sulfate. To compensate for incomplete destruction, an empirical correction factor of 1.3 is applied in the calculation of the result.

9.9 Carbonates

The *rapid titration method* by Piper (also called *acid neutralization method*) is used. The sample is treated with dilute HCl and the residual acid is titrated. The results are referred to as *calcium carbonate equivalent* as the dissolution is not selective for calcite, and other carbonates such as dolomite are dissolved as well.

Note: Other procedures such as the *Scheibler volumetric method* or the *Bernard calcimeter* may also be used.

9.10 Gypsum

Gypsum is dissolved by shaking the sample with water. It is then selectively precipitated from the extract by adding acetone. This precipitate is re-dissolved in water and the Ca concentration is determined as a measure for gypsum. This method also extracts anhydrite.

9.11 Cation exchange capacity (CEC) and exchangeable base cations

The ammonium acetate pH 7 method is used. In saline soils, the readily soluble salts have to be washed out before starting the procedure. The sample is percolated with ammonium acetate (pH 7) and the base cations are measured in the percolate. The sample is subsequently percolated with sodium acetate (pH 7), the excess salt is then removed and the adsorbed Na exchanged by percolation with ammonium acetate (pH 7). The Na in this percolate is a measure for the CEC.

Alternatively, after percolation with ammonium acetate, the sample can be washed free of excess salt, the whole sample distilled and the evolved ammonia determined.

Percolation in tubes may be replaced by shaking in flasks. Each extraction must be repeated three times and the three extracts should be combined for analysis.

Note 1: Other procedures for CEC may be used provided the determination is done at pH 7.
Note 2: In special cases where CEC is not a diagnostic criterion, e.g. saline and alkaline soils, the CEC may be determined at pH 8.2.
Note 3: The base saturation of saline, calcareous and gypseous soils can be considered to be 100%.

9.12 Exchangeable aluminium and exchange acidity

Exchangeable Al is released upon exchange by an unbuffered 1 *M* KCl solution.

Exchange acidity is extracted by a barium chloride-triethanolamine solution, buffered at pH 8.2. The extract is back-titrated with HCl.

9.13 Calculations of CEC and exchangeable cations

These calculations are usually only provided for *mineral material*.

CEC

The CEC is given in $cmol_c\ kg^{-1}$ soil. The CEC kg^{-1} clay is calculated by dividing the CEC kg^{-1} soil by the clay content. Principally, this is only correct if, before doing that, the CEC kg^{-1} soil attributed to the organic matter is subtracted. But we do not have a reliable method to detect the contribution of the organic matter to the CEC. Therefore, it is recommended to do the calculation as if all the CEC were provided by clay. If the organic matter content is low, the error is negligible.

Saturations at pH 7

The base saturation (BS) refers to the exchangeable base cations and is calculated as:
exchangeable (Ca+Mg+K+Na) x 100 / CEC.
The exchangeable sodium percentage (ESP) is calculated as:
exchangeable Na x 100 / CEC.
The input data are given in $cmol_c\ kg^{-1}$ and the results in %.

If the data for the base saturation are not available, the pH_{water} can be used instead. If this is also not available, the pH_{KCl} can be used. The correlations between base saturation and pH depend on the amount of organic matter and show an extremely high variance. The following pH values are recommended for a base saturation of 50%:

Table 9.2: pH values corresponding to a base saturation of 50%

C_{org} (%)	pH_{water}	pH_{KCl}
< 2	5.0	4.0
≥ 2 to < 7.5	5.3	4.5
≥ 7.5 to < 20	5.7	5.0

Relationships between cations

Exchangeable ions are given in $cmol_c\ kg^{-1}$. For some soils, the relationship between the sum of exchangeable base cations and exchangeable Al is required. If the data for exchangeable ions are not available, the pH_{water} can be used instead. If this is also not available, the pH_{KCl} can be used. The correlations between exchangeable ions and pH depend on the amount of organic matter and show an extremely high variance. The following pH values are recommended:

Table 9.3: pH values corresponding to relationships between cations

	exchangeable (Ca+Mg+K+Na) = exchangeable Al		exchangeable (Ca+Mg+K+Na) ≥ 4 times the exchangeable Al		exchangeable Al > 4 times the exchangeable (Ca+Mg+K+Na)	
C_{org} (%)	pH_{water}	pH_{KCl}	pH_{water}	pH_{KCl}	pH_{water}	pH_{KCl}
< 2	4.6	3.8	5.5	4.7	3.9	3.2
≥ 2 to < 7.5	4.9	4.1	5.9	5.0	4.2	3.4
≥ 7.5 to < 20	5.4	4.6	6.3	5.5	4.5	3.7

9.14 Extractable iron, aluminium, manganese and silicon

These analyses comprise:

- Fe_{dith}, Al_{dith}, Mn_{dith}: Dithionite-citrate-bicarbonate dissolves:
  - Fe particularly from Fe(III) oxides, hydroxides and oxide-hydroxides;
  - Al from Fe oxides, where the Al has substituted the Fe, and Al associated to reducible oxides;
  - Mn particularly from Mn(IV) oxides, hydroxides and oxide-hydroxides.

  Both the Mehra & Jackson (1958) and the Holmgren (1967) procedures may be used, with membrane filtration (0.45 µm).
- Fe_{ox}, Al_{ox}, Si_{ox}, Mn_{ox}: Oxalate (0.2 M ammonium oxalate buffered to pH 3 with 0.2 M oxalic acid) dissolves:
  - Fe from poorly crystalline oxides, hydroxides and oxide-hydroxides (such as ferrihydrite), and partially Fe from goethite, lepidocrocite, maghemite and magnetite, and partially Fe from organic associations;
  - Al from Fe oxides, where the Al has substituted the Fe, from hydroxy-interlayers of phyllosilicates, and partially Al from short-range ordered aluminosilicates (such as allophane and imogolite), and partially Al from organic associations, and the adsorbed Al;
  - Si partially from short-range ordered aluminosilicates (such as allophane and imogolite);
  - Mn from oxides, hydroxides and oxide-hydroxides (completely).

  The procedure according to Blakemore et al. (1987) may be used, with membrane filtration (0.45 µm).

Note: Al_{dith} and Mn_{ox} are not used for definitions in WRB. For further review of methods see Rennert (2019).

9.15 Salinity

Attributes associated with salinity in soils are determined in the *saturation extract*. The attributes include: pH, electrical conductivity (EC_e), sodium adsorption ratio (SAR) and the cations and anions of the dissolved salts. These include Ca, Mg, Na, K, carbonate and bicarbonate, chloride, nitrate and sulfate. The SAR and the exchangeable sodium percentage (ESP) may be estimated from the concentrations of the dissolved cations.

The determination in the saturation extract is often difficult. Alternatively, the conductivity and the cations and anions may be detected in a 1:2.5 solution and recalculated to the saturation extract (see Chapter 8.4.28).

9.16 Phosphate and phosphate retention

These analyses comprise:

- *Mehlich-3 method*: Extraction with a solution of 0.2 *M* glacial acetic acid, 0.25 *M* ammonium nitrate, 0.015 *M* ammonium fluoride, 0.013 *M* nitric acid, and 0.001 *M* ethylene diamine tetraacetic acid (EDTA) (Mehlich 1984).

- For phosphate retention, the *Blakemore method* is used. The sample is equilibrated with a phosphate solution at pH 4.6 and the proportion of phosphate withdrawn from solution is determined (Blakemore et al., 1987).

9.17 Mineralogical analysis of the sand fraction

After removal of cementing and coating materials, the sand is separated from the clay and silt by wet sieving. From the sand, the fraction 63–420 µm is separated by dry sieving. This fraction is divided into a *heavy fraction* and a *light fraction* with the aid of a high-density liquid: a solution of sodium polytungstate with a specific density of 2.85 kg dm^{-3}. Of the *heavy fraction*, a microscopic slide is made; the *light fraction* is stained selectively for microscopic identification of feldspars and quartz. The analysis requires a petrographic microscope.

Volcanic glass can usually be recognized as isotropic grains with vesicles.

9.18 X-ray diffractometry

X-ray diffraction (XRD) can be used to analyze (1) the powder of the fine earth or (2) the clay fraction separated from soil.

9.19 Total reserve of bases

There are two methods to analyze the total content of elements: XRD (see Chapter 9.18) and an extract with HF and $HClO_4$. The obtained values for Ca, Mg, K and Na are used to calculate the total reserve of bases.

9.20 Sulfides

Reduced inorganic S is converted to H_2S by a hot acidic $CrCl_2$ solution. The evolved H_2S is trapped quantitatively in a Zn acetate solution as solid ZnS. The ZnS is then treated with HCl to release H_2S into solution, which is quickly titrated with I_2 solution to the blue-coloured end point indicated by the reaction of I_2 with starch (Sullivan et al., 2000). Caution: Toxic residues have to be managed carefully.

9.21 References

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10 Annex 3: Horizon and layer designations

This annex provides the horizon and layer symbols for soil description. The designations are based on field characteristics (Annex 1, Chapter 8) and laboratory characteristics (Annex 2, Chapter 9). In some cases, the processes that have led to these characteristics, may no longer be active. **Only brief descriptions are given here, which are not intended to be definitions as in the diagnostics of the WRB.** In most cases, no quantitative criteria are given.

The **fine earth** comprises the soil constituents ≤ 2 mm. The **whole soil** comprises fine earth, coarse fragments, *artefacts*, cemented parts, and dead plant residues of any size. (see Chapter 2.1, General rules, and Annex 1, Chapters 8.3.1 and 8.3.2).

A **litter layer** is a loose layer that contains > 90% (by volume, related to the fine earth plus all dead plant residues) recognizable dead plant tissues (e.g. undecomposed leaves). Dead plant material still connected to living plants (e.g. dead parts of *Sphagnum* mosses) is not regarded to form part of a litter layer. The **soil surface** (0 cm) is by convention the surface of the soil after removing, if present, the litter layer and, if present, below a layer of living plants (e.g. living mosses). The **mineral soil surface** is the upper limit of the uppermost layer consisting of mineral material (see Chapter 2.1, General rules, and Annex 1, Chapter 8.3.1).

A **soil layer** is a zone in the soil, approximately parallel to the soil surface, with properties different from layers above and/or below it. If at least one of these properties is the result of soil-forming processes, the layer is called a **soil horizon**. In the following, the term layer is used to indicate the possibility that soil-forming processes did not occur. A **stratum** (see Chapter 10.4) is the result of geological processes and may comprise more than one layer.

We distinguish the following layers (see Chapter 3.3):

- **Organic layers** consist of organic material.
- **Organotechnic layers** consist of organotechnic material.
- **Mineral layers** are all other layers.

The designation consists of a capital letter (master symbol), which in most cases is followed by one or more lowercase letters (suffixes). Rules are given for the combinations of symbols in one layer and for layer sequences.

The word **rock** comprises both consolidated and unconsolidated material. The word **oxides**, in the following, includes oxides, hydroxides and oxide-hydroxides.

10.1 Master symbols

Table 10.1: Master symbols

Symbol	Criteria
H	Organic or organotechnic layer, not forming part of a litter layer; water saturation > 30 consecutive days in most years or drained; generally regarded as peat layer or organic limnic layer. Nota bene: • Under water saturation, completely undecomposed organic layers, consisting of 100% (by volume, related to all dead plant residues) recognizable dead plant tissues, may exist. However, most H layers underwent at least some decomposition, show < 100% (by volume) recognizable dead plant tissues and are considered to be soil horizons. • If the H is used for organotechnic layers, the suffix u is mandatory.
O	Organic horizon or organotechnic layer, not forming part of a litter layer; water saturation ≤ 30 consecutive days in most years and not drained; generally regarded as non-peat and non-limnic horizon. Nota bene: If the O is used for organotechnic layers, the suffix u is mandatory.
A	Mineral horizon at the mineral soil surface or buried; contains organic matter that has at least partly been modified in-situ; soil structure and/or structural elements created by cultivation in ≥ 50% (by volume, related to the fine earth), i.e. rock structure, if present, in < 50% (by volume); cultivated mineral layers are designated A, even if they belonged to another layer before cultivation.
E	Mineral horizon; has lost by downward movement within the soil (vertically or laterally) one or more of the following: Fe, Al, and/or Mn species; clay minerals; organic matter.
B	Mineral horizon that has (at least originally) formed below an A or E horizon; rock structure, if present, in < 50% (by volume, related to the fine earth); one or more of the following processes of soil formation: • formation of soil aggregate structure • formation of clay minerals and/or oxides • accumulation by illuviation processes of one or more of the following: Fe, Al, and/or Mn species; clay minerals; organic matter; silica; carbonates; gypsum • removal of carbonates or gypsum. Nota bene: B horizons may show other accumulations as well.
C	Mineral layer; unconsolidated (can be cut with a spade when moist), or consolidated and more fractured than the R layer; no soil formation, or soil formation that does not meet the criteria of the A, E, and B horizon.
R	Consolidated rock; air-dry or drier specimens, when placed in water, will not slake within 24 hours; fractures, if present, occupy < 10% (by volume, related to the whole soil); not resulting from the cementation of a soil horizon.
I	≥ 75% ice (by volume, related to the whole soil), permanent, below an H, O, A, E, B or C layer.
W	Permanent water above the soil surface or between layers, may be seasonally frozen.

10.2 Suffixes

If not stated otherwise, the descriptions are related to the **fine earth** (see Chapter 2.1).

Table 10.2: Suffixes

Symbol	Criteria	Combination with
a	Organic material in an advanced state of decomposition; after gently rubbing, ≤ one sixth of the volume (related to the fine earth plus all dead plant residues) consists of recognizable dead plant tissues [a like **a**dvanced].	H, O
b	Buried horizon; first, the horizon has formed, and then, it was buried by mineral material [b like **b**uried].	H, O, A, E, B
c	Concretions and/or nodules (only used if following another suffix (k, q, v, y) that indicates the accumulated substance) [c like **c**oncretion].	
d	Drained [d like **d**rained].	H
e	Organic material in an intermediate state of decomposition; after gently rubbing, ≤ two thirds and > one sixth of the volume (related to the fine earth plus all dead plant residues) consist of recognizable dead plant tissues [e like interm**e**diate].	H, O
	Saprolite [e like saprolit**e**].	C
f	Permafrost [f like **f**rost].	H, O, A, E, B, C
g	Accumulation of Fe and/or Mn oxides (related to the fine earth plus accumulations of Fe and/or Mn oxides of any size and any cementation class) predominantly inside soil aggregates, if present, and loss of these oxides on aggregate surfaces (A, B, and C horizons), or loss of Fe and/or Mn by lateral subsurface flow (pale colours in ≥ 50% of the exposed area; E horizons); transport in reduced form [g like sta**g**nic].	A, B, C E
h	Significant amount of organic matter; in A horizons at least partly modified in situ; in B horizons predominantly by illuviation; in C horizons forming part of the parent material [h like **h**umus].	A, B, C
i	Organic material in an initial state of decomposition; after gently rubbing, > two thirds of the volume (related to the fine earth plus all dead plant residues) consist of recognizable dead plant tissues [i like **i**nitial].	H, O
	Slickensides and/or wedge-shaped aggregates [i like sl**i**ckenside].	B
j	Accumulation of jarosite and/or schwertmannite (related to the fine earth plus accumulations of jarosite and/or schwertmannite of any size and any cementation class) [j like **j**arosite].	H, O, A, E, B, C

k	Accumulation of secondary carbonates (related to the fine earth plus accumulations of secondary carbonates of any size and any cementation class), evident by one or both of the following: • visible even in moist state • has a calcium carbonate equivalent of ≥ 5% higher (absolute, related to the fine earth plus accumulations of secondary carbonates of any size and any cementation class) than that of an underlying layer and no *lithic discontinuity* between the two layers [k like German ***K**arbonat*].	H, O, A, E, B, C
l	Accumulation of Fe and/or Mn in reduced form by upward-moving capillary water with subsequent oxidation (related to the fine earth plus accumulations of Fe and/or Mn oxides of any size and any cementation class): accumulation predominantly at soil aggregate surfaces, if present, and reduction of these oxides inside the aggregates [l like capi**ll**ary].	H, A, B, C
m	Pedogenic cementation in ≥ 50% of the volume (related to the whole soil); cementation class: at least moderately cemented (only used if following another suffix (k, l, q, s, v, y, z) that indicates the cementing agent) [m like ce**m**ented].	
n	Exchangeable sodium percentage ≥ 6% [n like **n**atrium].	E, B, C
o	Residual accumulation of large amounts of pedogenic oxides in strongly weathered horizons [o like **o**xide].	B
p	Modification by cultivation (e.g. ploughing); mineral layers are designated A, even if they belonged to another layer before cultivation [p like **p**lough].	H, O, A
q	Accumulation of secondary silica (related to the fine earth plus accumulations of secondary silica of any size and any cementation class) [q like **q**uartz].	A, E, B, C
r	Strong reduction [r like **r**eduction].	A, E, B, C
s	Accumulation of Fe oxides, Mn oxides and/or Al (related to the fine earth plus accumulations of Fe oxides, Mn oxides and/or Al of any size and any cementation class) by vertical illuviation processes from above [s like **s**esquioxide].	B, C
t	Accumulation of clay minerals by illuviation processes [t like German ***T**on*, clay].	B, C
u	Containing *artefacts* or consisting of *artefacts* (related to the whole soil) [u like **u**rban].	H, O, A, E, B, C, R
v	Plinthite (related to the fine earth plus accumulations of Fe and/or Mn oxides of any size and any cementation class) [the suffix v has no connotation].	B, C
w	Formation of soil aggregate structure and/or oxides and/or clay minerals (layer silicates, allophanes and/or imogolites) [w like **w**eathered].	B

x	Fragic characteristics (soil aggregates with a rupture resistance of at least firm and a brittle manner of failure, not allowing roots to enter the aggregates) [the x refers to the impossibility to enter the aggregates].	E, B, C
y	Accumulation of secondary gypsum (related to the fine earth plus accumulations of secondary gypsum of any size and any cementation class) [y like g**y**psum or Spanish ***y**eso*].	A, E, B, C
z	Presence of readily soluble salts [z like Dutch ***z**out*].	H, O, A, E, B, C
@	Cryogenic alteration.	H, O, A, E, B, C
α	Presence of primary carbonates (in R layers related to the rock, in all other layers related to the fine earth) [α like c**a**rbonate].	H, A, E, B, C, R
β	Bulk density ≤ 0.9 kg dm^{-3} [β like **b**ulk density].	B
γ	Containing ≥ 5% (by grain count) volcanic glasses in the fraction between > 0.02 and ≤ 2 mm [γ like **g**lass].	H, O, A, E, B, C
δ	High bulk density (natural or anthropogenic - not due to cementation (symbol ..m), not in *fragic horizons* (symbol x), not in layers with *retic properties* (symbol Bt/E)), so that roots cannot enter, except along cracks [δ like **d**ense].	A, E, B, C
λ	Deposited in a body of water (limnic) [λ like **l**imnic].	H, A, C
ρ	Relict features (only used if following another suffix (g, k, l, p, r, @) that indicates the relict feature) [ρ like **r**elict].	
σ	Permanent water saturation and no redoximorphic features [σ like **s**aturation].	A, E, B, C
τ	Human-transported natural material (related to the whole soil) [τ like **t**ransported].	H, O, A, B, C
φ	Accumulation of Fe and/or Mn in reduced form by lateral subsurface flow with subsequent oxidation (related to the fine earth plus accumulations of Fe and/or Mn oxides of any size and any cementation class) [φ like **f**low].	A, B, C

I and W layers have no suffixes.

Combination of suffixes:
1. The c follows the suffix that indicates the substance that forms the concretions or nodules; if this is true for more than one suffix, each one is followed by the c.
2. The m follows the suffix that indicates the substance that is the cementing agent; if this is true for more than one suffix, each one is followed by the m.
3. The ρ follows the suffix that indicates the relict features; if this is true for more than one suffix, each one is followed by the ρ.
4. If two suffixes belong to the same soil-forming process, they follow each other immediately; in the combination of t and n, the t is written first; rules 1, 2 and 3 have to be followed, if applicable.
   Examples: Btn, Bhs, Bsh, Bhsm, Bsmh.
5. If in a B horizon the characteristics of the suffixes g, h, k, l, o, q, s, t, v, or y are strongly expressed, the suffix w is not used, even if its characteristics are present; if the characteristics of the mentioned suffixes are weakly expressed and the characteristics of the suffix w are present as well, the suffixes are combined.
   Examples:
   Bwt (weak illuvial accumulation of clay minerals; characteristics of w present),

Btw (intermediate illuvial accumulation of clay minerals; characteristics of w present),
Bt (strong illuvial accumulation of clay minerals; characteristics of w present),
Nota bene: If the characteristics of the B horizon are absent (≥ 50 % rock structure, by volume, related to the fine earth), the horizon is named Ct.

6. In H and O layers, the i, e or a is written first.
7. The @, f and b are written last, if b occurs together with @ or f (only if other suffixes are present as well): @b, fb.
8. Besides that, combinations must be in the sequence of dominance, the dominant one first. Examples: Btng, Btgb, Bkcyc.

10.3 Transitional layers

If the characteristics of two or more master layers are superimposed to each other, the master symbols are combined without anything in between, the dominant one first, each one followed by its suffixes.
Examples: AhBw, BwAh, AhE, EAh, EBg, BgE, BwC, CBw, BsC, CBs.

If the characteristics of two or more master layers occur in the same depth range, but occupy distinct parts clearly separated from each other, the master symbols are combined with the slash (/), the dominant one first, each one followed by its suffixes.
Examples:
Bt/E (interfingering of E material into a Bt horizon),
C/Bt (Bt horizon forming lamellae within a C layer).

If a suffix applies to two or more master symbols, it is not repeated and follows the first master symbol.
Example: AhkBw (not: AhkBwk; not: AhBwk).

W cannot be combined with other master symbols. H, O, I, and R can only be combined using the slash.

10.4 Layer sequences

The sequence of the layers is from top to down with a hyphen in between. Examples see Chapter 10.5.

If lithic discontinuities occur, the strata are indicated by preceding figures, starting with the second stratum. I and W layers are not considered as strata. All layers of the respective stratum are indicated by the figure:
Example: Oi-Oe-Ah-E-2Bt-2C-3R.

If the suffix b occurs, the preceding figure and the suffix b are combined.
Example: Oi-Oe-Ah-E-Bt-2Ahb-2Eb-2Btb-2C-3R.

If two or more layers with the same designation occur, the letters are followed by figures. The sequence of figures continues across different strata.
Examples:
Oi-Oe-Oa-Ah-Bw1-Bw2-2Bw3-3Ahb1-3Eb-3Btb-4Ahb2-4C,
Oi-He-Ha-Cr1-2Heb-2Hab-2Cr2-3Crγ.

10.5 Examples for layer sequences

This Chapter provides for every RSG examples for layer sequences. These are just **examples**, and in every RSG other layer sequences occur as well. Some layer sequences occur in more than one RSG.

Histosols:
Hi-He-Ha-Haλ-Cr
Hi-Hef-Haf-Cf
Hi-Haγ-Haβ-Cr
Oi-Hid-Hed-He-Ha-Haλ-Cr
W-Hiλ-Heλ-Haλ-Cr
Oi-W-Hiλ-Heλ-Haλ-Cr
Oi-I
Oi-Oe-Oa-R
Oi-Oe-Ru
Oi-Oe/C-Oa/C-R
Anthrosols:
Ap-Bw-C
Arp-Ardp-Bg-C
Technosols:
Ahτ-2Bwu-2Cu
Ah-2Our-3C
Ru-2Cu-3Bw-3C
Ahτ-2Ru
Cryosols:
Oi-Ah-Bw@-Bwf-Cf
Oi-Oe-Ah-Cf
Leptosols:
Oi-Oe-Ah-R
Oi-Ah-CBw-C
Solonetz:
Ah-E-Btn-C
Vertisols:
Ah-Bw-Bi-C
Solonchaks:
Ah-Bz-Cz
Gleysols:
Ah-Bl-Br-Cr
Ah-Br-Cr
Ah-Bl-C
Ah-Cσ
He-Cr
W-Heλ-Cr
W-Ahr-Cr
Andosols:
Ah-Bwγ-Cγ
Ah-Bwβ-Cγ

Podzols:
Oi-Oe-Oa-AhE-E-Bhs-Bs-C
Oi-Oe-Oa-AhE-E-Bhs-BsC-C
Oi-Oe-Oa-AhE-E-Bh-C
Oi-Oe-Oa-AhE-E-Bs-C
Plinthosols:
Ah-Eg-Bvg-C
Ah-Bv-Bo-C
Ah-Bvc-Bo-C
Ah-Bvm-Bo-C
Ah-Bvm-Ce-C
Planosols:
Oi-Oe-Ah-Eg-2Bg-2C
Ah-Eg-Btg-C
Stagnosols:
Ah-Bg-C
Oi-Ah-Eg-Btg-C
Nitisols:
Ah-Bo-C
Ferralsols:
Ah-Bo-C
Ah-Bo-Ce-C
Ah-Bw-Bo-Ce-C
Chernozems:
Ah-Ck
Ah-Bwk-C
Ah-Bw-Bwk-C
Kastanozems:
Ah-Ck
Ah-Bwk-C
Ah-Bk-C
Phaeozems:
Ah-C
Ah-Bw-C
Ah-Bw-Bwk-C
Ah-E-Bt-C
Umbrisols:
Ah-C
Oi-Ah-Bw-C
Durisols:
Ah-Bqc-C
A-Bqc-C
A-Bqm-C
A-Bw-Bqm-C
A-Bk-Bqm-C

Gypsisols:
Ah-Cy
A-By-C
A-Bk-By-C
A-By-Bk-C
A-Bym-C
Calcisols:
Ah-Ck
Ah-Bk-Cα
A-Bkc-C
A-Bkm-C
A-Bw-Bk-Cα
Ah-E-Btk-Bk-C
Retisols:
Ah-E-Bt/E-Bt-C
Acrisols, Lixisols, Alisols, Luvisols:
Ah-E-Bt-C
Cambisols:
Ah-Bw-C
Oi-Oe-Ah-Bw-C
Ah-Bwφ-C
Fluvisols:
Ah-C1-2C2-3C3
Arenosols:
A-C
Ah-C
Regosols:
A-C
Ah-C
Ahτ-C
Ah-Cγ

10.6 References

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11 Annex 4: Soil description sheet

The soil description sheet is provided as an open-access excel file on the WRB homepage. For cells coloured in brown, a code is required. For cells coloured in green, figures or free text are required. The excel file representing the whole Annexes 1 (Chapter 8) and 3 (Chapter 10) is relatively long.

You may also prepare your individual short version. If you are sure that in the area of your soil survey certain characteristics cannot occur, you may delete the respective columns. (Example: If your survey is not in a desert, you may delete the columns referring to desert features.)

12 Annex 5: Guidance on database set-up

Setting up a database for soil description and classification according to WRB is not a simple task due to often conflicting requirements regarding issues like

- Data evaluation aims and needs
- Data reusability
- Data quality
- Data and system security
- Performance of database operations
- Experience of database administrators and users

and last but not least, the complex data structure necessary to cover parameters with their auxiliary data and the complexity of WRB soil name syntax.

The single-user one-project data collection can be done in a spreadsheet approach, which is unsuitable for multi-user information systems that need to maintain data security for decades. Introducing WRB 2022 into an existing soil or even land information system asks for different solutions than a newly set-up single-aim database. Even if we consider the most widespread relational database approach, not all of the database management systems provide any logical operation and further possibilities foreseen in the *Structured Query Language (SQL)*, and they differ largely in performance and the use of additional programming.

The WRB homepage provides guidance and practice examples for database solutions suited to the fourth edition of WRB.

13 Annex 6: Colour symbols for RSG maps

This annex provides **suggestions** for colours in maps showing the RSGs. The suggestions follow roughly the colour choices in the atlases edited by the Joint Research Centre of the European Commission.

The guidelines for creating map legends are given in Chapter 2.5. A map unit consists of

- a dominant soil only
- a dominant soil plus a codominant soil and/or one or more associated soils
- one, two or three codominant soils with or without one or more associated soils.

It is strongly recommended to indicate more than just one soil in the map units, because the restriction to only one soil gives often an insufficient or even misleading image.

It is recommended to use colour symbols and alphanumeric codes to allow the map reader a correct identification of the mapping unit of each polygon. (For raster datasets, only colours can be used.) The colour represents the dominant soil or, if absent, the major codominant soil, only. The other soils are indicated by adding alphanumeric codes. On the first scale level, nothing else is required. If you add optional qualifiers, use alphanumeric codes. The principal qualifiers added at the second and third scale level are also indicated by alphanumeric codes. These are selected by the soil scientist, who makes the map. In complex mapping units with several soils, codominant and associated soils may be mentioned in the mapping unit explanation, only.

Table 13-1: Colour symbols for RSG maps

RSG	R	G	B	RGB Hex
Acrisol (AC)	247	152	4	#F79804
Alisol (AL)	255	255	190	#FFFFBE
Andosol (AN)	254	0	0	#FE0000
Anthrosol (AT)	207	152	4	#CF9804
Arenosol (AR)	245	212	161	#F5D4A1
Calcisol (CL)	254	244	0	#FEF400
Cambisol (CM)	254	190	0	#FEBE00
Chernozem (CH)	145	77	53	#914D35
Cryosol (CR)	75	61	172	#4B3DAC
Durisol (DU)	239	228	190	#EFE4BE
Ferralsol (FR)	255	135	33	#FF8721
Fluvisol (FL)	0	254	253	#00FEFD
Gleysol (GL)	128	131	217	#8083D9
Gypsisol (GY)	254	246	164	#FEF6A4
Histosol (HS)	112	107	102	#706B66
Kastanozem (KS)	202	147	127	#CA937F
Leptosol (LP)	209	209	209	#D1D1D1
Lixisol (LX)	255	190	190	#FFBEBE
Luvisol (LV)	250	132	132	#FA8484
Nitisol (NT)	255	167	127	#FFA77F
Phaeozem (PH)	189	100	70	#BD6446
Planosol (PL)	247	125	58	#F77D3A
Plinthosol (PT)	115	0	0	#730000
Podzol (PZ)	12	217	0	#0CD900
Regosol (RG)	254	227	164	#FEE3A4
Retisol (RT)	254	194	194	#FEC2C2

Solonchak (SC)	254	0	250	#FE00FA
Solonetz (SN)	249	194	254	#F9C2FE
Stagnosol (ST)	64	192	233	#40C0E9
Technosol (TC)	145	0	157	#91009D
Umbrisol (UM)	115	142	127	#738E7F
Vertisol (VR)	197	0	255	#C500FF

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